OPERATING AND INSTRUCTION MANUAL

MODELS 214A, B, & C

PHASE ANGLE VOLTMETER

Patents are Pending for a Number of Circuits Used in This Instrument

Revised, 7/20/66 and
3/17/71
1/2/74
7/20/74

NORTH ATLANTIC INDUSTRIES, INC.
Plainview New York

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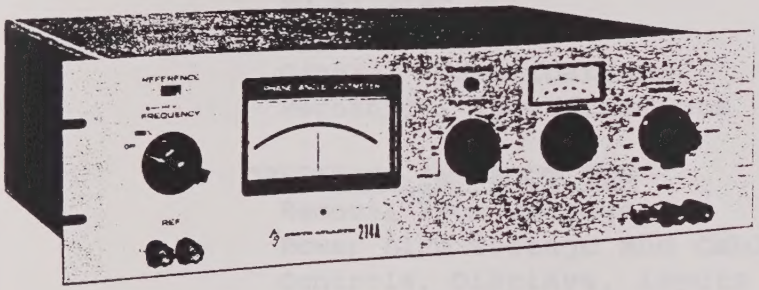
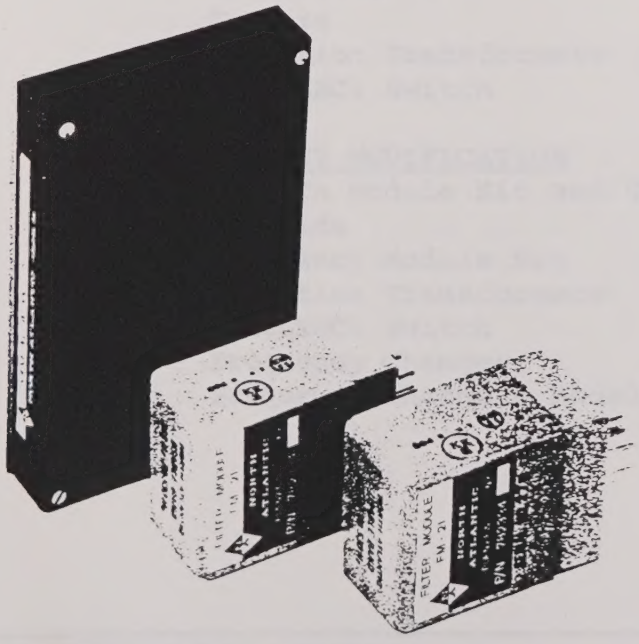


MODEL 214A

1 Frequency - 400Hz
Rack Mounting

MODEL 214C

4 Frequency - 60Hz,
400Hz, 800Hz, 10KHz.
Bench mounting
(includes bench kit)



PLUG IN MODULE KIT KM-30
Consists of:

PM-10 Phase Module
FM-21 Filter Pair
Frequency Decal

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Revised,
7/20/66

ERRATA SHEET

MODELS 214A, B, & C

Page 2.9 - Paragraph now reads:

2. Switch the FUNCTION Selector to the REF ADJ Position, assuring the REF ADJ potentiometer on the Range Switch is in the FIXED position.

Revised 2-6-75

CAUTION

High voltage exists at several points in the instrument. Normal precautions consistent with good practice should be taken to reduce shock hazard.

A potential shock hazard exists when ungrounded power source or ungrounded case operation is employed. Persons operating the instrument should be made aware of and take precautions against this condition.

North Atlantic Industries, Inc. cannot be held responsible for damage to person or property in the process of or as a result of maintenance, calibration, or setting up of the instrument.

SECTION I

GENERAL DESCRIPTION

The Model 214 Phase Angle Voltmeter is a completely transistorized modularized instrument which combines the ability to measure both phase angle and magnitude of complex AC signals and vector components with respect to a reference voltage. Designed to operate phase sensitively within a frequency range of 30Hz to 20KHz, it utilizes passive phase shifter circuits to assure long term stability and high accuracy over the spectrum. As a TOTAL voltmeter, the Model 214 is capable of measuring signals within a frequency range of 10Hz to 100KHz. The Model 214C (below) has its frequency response limited to that of the particular isolation transformer in the circuit (see Transformer Spec, Page 1.7 and Isolation Transformers, Page 3.15).

This instrument is characterized by its capability to operate at four separate phase-sensitive frequencies. These frequencies may be changed simply by replacing the frequency determining plug in modules, consisting of a pair of matched harmonic rejection filters and a plug-in frequency module. The instrument can be supplied with 1, 2, 3, or 4 sets of plug-in modules. Any unused channel may be left open for field addition if required. Additional or replacement kits of plug-in modules are available and may be added at any time in the future. Panel decals designating frequency are supplied as part of the additional kit.

Front panel controls permit instantaneous selection of range, function, and frequency.

As a phase-sensitive null meter, the Model 214's 2uv nulling sensitivity permits high resolution ratiometric measurements. This allows measurements of low-level voltages of the reference frequency in the presence of noise, hum, and other spurious signals. As a phase meter, angles are read on a high resolution, parallax-free scale calibrated in 0.5^{o} increments.

The Model 214 is available in three basic configurations:

MODEL 214A - No Signal or Reference Isolation:

The Model 214A will perform all the basic functions for which the instrument has been designed, except that it does not contain any means for isolating the reference or signal inputs.

MODEL 214B - Reference Isolation Only:

The Model 214B is identical to the Model 214A with the exception of the added reference isolation transformer. The instrument is factory wired to accept the plug-in reference isolation transformer, TM42.

MODEL 214C - Both Reference and Signal Isolation:

The Model 214C differs from the Model 214B not only by the addition of signal isolation, but it also includes a front panel switch for switching the transformer in or out of the signal input circuit. It also includes a special attenuator which is used to limit the voltage applied to the transformer at low frequencies. In order to prevent damage to the transformer, in the event of inadvertent application of excessive voltage, fuses are provided on the front panel.

Signal isolation is accomplished in the Model 214C by means of two separate transformers, each designed for specific frequency bands (see Specifications, Page 1.7).

NOTE: The provisions for all isolation transformers require factory wiring. The Model 214 cannot be modified in the field to convert from one version to another.

APPLICATIONS

A. Phase sensitive null indicator.

B. Measures separately the In-Phase and Quadrature components of an AC signal.

C. Measures phase shift in any AC system.

D. Sensitive AC electronic voltmeter.

E. Testing of servos, computers, synchros, resolvers, inductosyns.

F. Precise AC ratiometry.

G. Phasing of servo motors, chopper amplifiers, magnetic amplifiers.

H. Measuring both torque and non-torque producing signals in servo amplifiers.

I. Align carrier amplifier and notch networks.

J. Impedance meter.

K. Power factor meter.

L. Measuring response of vibrational system.

Detailed descriptions of these applications are shown in the Application Notes appended hereto.

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MODEL 214A, 214B, 214C

PHASE ANGLE VOLTMETER

GENERAL SPECIFICATION

The following specification applies to all North Atlantic Models 214A, 214B, 214C Phase Angle Voltmeters. Where a special modification or variation is involved, the governing specification will either be a separate specification control document, the buyer's purchase order, or a supplement contained in this manual. Specifications for special instruments are identified by the specification "S" number appearing on the instrument nameplate, e.g., 214A-S1234.

In addition, the original frequencies of operation as installed at the factory will be identified on this same nameplate. Since these frequencies may be changed in the field, it is necessary to specify all desired frequencies of operation as well as the "S" number when purchasing new instruments.

Voltage Range (Full Scale Output):	300uv to 300V in 13 ranges.
Range Vernier:	Adjustable from 0.3 full scale to full scale (10 x overload capability is maintained at all settings of the vernier).
Frequency Range:	Total Voltage - 10Hz to 100KHz (Direct) (See Page 1.7 for Trans.) Phase Sensitive - 1, 2, 3, or 4 frequencies from 30Hz to 20KHz. (Frequency may be varied ±5%.) See Page 4.4 for channel combinations.

Accuracy:

Voltage:

Total Mode: 10Hz-50KHz = ±2%
Direct 50KHz-100KHz = ±5%

Fund: ±2% at frequency of operation.

Phase: ±1° as read on the Phase Dial or when using E cos θ characteristic, ±3% of full scale angle.

NOTE: Transformer Mode performance in Model C instruments, are affected by the transformer itself. Refer to Section III, Page 3.15, for the details of these characteristics. The nominal results shown must be "added" to the above. Special transformers are available for improved performance at frequency extremes.

Calibration:

Voltage: Zero center, low stiction meter calibrated 3-0-3 and 10-0-10 scales.

Phase Dial: Continuously calibrated from -6° to +96° over four quadrants 0°, 90°, 180°, 270°.

Resolution: 0.2°.

Signal Input Impedance:

Model A; 10 megohms, shunted by 65uuf nominal.

Model B: 10 megohms, shunted by 65uuf nominal.

Model C: 10 megohms, shunted by 75uuf, nominal (Direct Mode).

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Signal Input Impedance: (continued)	TM40 = 500K at 400Hz (Trans. Mode). When alternate 1000:1 attenuator is used, the input impedance will be 100K in the 10V to 300V ranges. TM41 = 250K at 2.5KHz (Trans. Mode). NOTE: For more detailed specifications of TM40 and TM41, see Transformer data of Section III, Page 3.15.
Reference Input Impedance:	Model 214A: 10 megohms, shunted by 65uuf nominal. Models 214B and 214C: 100K ohms, shunted by 120uuf nominal.
Reference Input Voltage:	Model 214A: 50mV to 150V max. Models 214B and 214C: 1.5V min. to 150V max. (See Section II, Page 2.9)
Input DC Voltage Level:	Models 214A and 214B: 400V max. Model 214C: 0V (with no external blocking capacitor. See Section II, Page 2.6)
Overload:	10 x overload capability. Overload light will ignite at approximately 11 x full scale setting.
Noise:	Less than 15uV, Total and Fund Modes.
Nulling Sensitivity:	Less than 2uV, Phase Sensitive Modes.
Harmonic Rejection:	Fundamental: See Diagram, Figure 3.6 (Page 3.13) Phase Sensitive: 40DB to 70DB depending on fundamental frequency, harmonic order and filter.

Non-Coherent Signal Rejection:	For frequencies removed from signal frequency by approximately 5Hz or more (effective pass band of meter movement) response is essentially nil for levels up to 10 x the value of the full scale in use. Appropriate filters can increase the allowable level of the non-coherent signal to 300 times the value of the full scale in use on the most sensitive scales.
Power:	115V, 125V, 230V, 250V ±10% 50-440Hz, 40W.
Fuse:	For 115V, 125V Power - .5A Type 3AG For 230V, 250V Power - .25A Type 3AG Signal Transformer - 1/16A, Type 3AG, Slo-Blo (Resistance not to exceed 30Ω).
Accessory Plug-In Modules:	Model TM42 - Reference Isolation Transformer: Frequency Range - 30Hz to 20KHz Voltage Range - 1V to 300V when used in 214B or 214C. Model TM40 - Signal Isolation Transformer (Low Frequency): Frequency Range - 30Hz to 2.5KHz Voltage Range - to 300V Max. when used in 214C. Common Mode (at 400Hz): Zero Source Impedance - .001% max. 1K Source Impedance - .003% max.

Accessory Plug-In Modules: (Continued)

Model TM41- Signal Isolation Transformer (High Frequency):

Frequency Range - 2.5KHz to 20KHz
Voltage Range - to 300V max. when used in 214C.

Common Mode (@ 2.5KHz):
Zero Source Impedance - .001%
1K Source Impedance - .003%.

For more detailed specifications, see the transformer data of Section III, Page 3.15.

Special transformers are available for particular applications.

MECHANICAL SPECIFICATIONS

Size:	Panel is 5-1/4" x 19"W. Depth behind panel is 12".
Weight:	20 to 25 lbs. depending on number of modules included.
Mounting:	Rack or bench mounted.
Front Panel Paint:	Gray #26440 per Fed. Std. 595
Front Panel Marking:	Black #37038 per Fed. Std. 595
Line Cord:	6' long, std.
Front Panel Input:	Inputs are standard, 5-way binding posts, spaced on 3/4" centers. Ground terminals are colored black and marked Ground.

NOTE: See Section IV, Page 4.3, for mechanical specifications of plug-in modules and plug-in isolation transformers.

SECTION II

OPERATING INSTRUCTIONS

REMOVAL FROM PACKAGE

This instrument has been thoroughly tested, inspected, and evaluated at the factory prior to shipment. Particular care has been taken in the design of the special wrapping and packaging material used in the container to ensure that no damage result from the typical handling encountered during shipment. However, upon removal from package, the instrument should be externally inspected for any obvious damage. Should such be observed, refer to the Warranty Policy previously presented.

Prior to making any connection, check the meter to see that it reads 0. If it does not, reset the meter to read 0 by means of the Zero Adjust screw which may be reached through the front panel. This adjustment must be done with the power off and with the instrument in a horizontal or near horizontal position.

POWER LINE VOLTAGE AND CABLE

The Model 214 is normally wired for 115V operation. If it is desired to operate the instrument from 230V source, refer to the transformer conversion illustration of Figure 5.1 for the correct procedure.

NOTE: Be sure to use the proper fuses for the desired operating voltage, 115V, 125V source will be .5 amp Type 3AG, and 230V, 250V source will be .25 amp, Type 3AG fuse.

All electrical circuit and power grounds are floating with respect to the chassis. The instrument is supplied with a three prong power plug. The round pin is wired to the chassis. Common grounding of power, chassis, and circuit ground is accomplished by means of a link on the signal input terminals. The circuit ground must be connected to chassis ground either at the input terminals

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or remotely. Dependent upon specific application, it may be more desirable to wire the chassis such that it is not connected directly to house ground. In those cases, extreme caution must be taken to avoid any personal injuries due to the resultant shock hazard. As a general rule, every effort must be made to ensure that the chassis is wired to a house ground at all times.

CONTROLS, DISPLAYS, INPUTS

Prior to attempting to operate this instrument, it is advisable that the user familiarize himself with every control, display, and input connection as described below.

FREQUENCY Switch

The Power Switch for the Model 214 is located on the FREQUENCY Switch. The instrument is turned on by moving the outer knob to any of the frequencies designated on the front panel. When the switch is placed in any of these positions, the meter face will be illuminated.

The Phase-Sensitive frequency to be measured is selected by setting this same outer knob to the frequency desired. This selects the proper frequency and phase-sensitive components.

REFERENCE HI-LO Selector

The REFERENCE HI-LO selector switch is located directly above the FREQUENCY switch and is a slide switch which inserts an attenuator in the HI position to allow the use of high level reference inputs.

Reference Vernier

The Reference Vernier Control is the center knob located concentrically with the FREQUENCY Switch and is used for

adjusting the reference level to read half scale (red line) on the meter. This control is used when the FUNCTION Selector is in the REF ADJ and the small red REF ADJ light is on.

FUNCTION Selector

The FUNCTION Switch selects the desired mode of operation for the instrument. In the four Phase Angle Voltmeter positions, the instrument is connected so that it may read a voltage E cos θ where θ is the angle by which the signal vector leads the reference vector. Any of the four quadrants may be selected over which the calibrated phase shifter will operate. Thus, the total angle by which the reference vector shifted in degrees will be either 0^{o}, 90^{o}, 180^{o}, or 270^{o} plus the reading of the Phase Dial.

In the TOTAL Position, the instrument functions as a standard voltmeter and will read all voltages over a frequency range of 10Hz to 100KHz. In the FUNDamental position, the instrument will read the total vector of the fundamental component of the input signal (See Figure 3.6 for filter characteristics).

The FUNCTION Selector must be positioned in the REF ADJ position in order to make the proper reference adjustment. Note that in this position, the red light marked REF ADJ will be turned on.

RANGE Selector

The RANGE Selector is a rotary switch which selects the proper attenuators for the desired full scale voltage by means of the outer knob. The center concentric knob is a range vernier control which permits the adjustment for full scale sensitivity, as desired for deviation measurements and extension of overload capability (See Page 2.11).

This control will turn on the VARIABLE light on the front panel which indicates an uncalibrated condition exists. The control must be in the extreme clockwise position for calibrated operation.

Phase Dial

The Phase Dial is calibrated to read the degrees of phase shift introduced by the calibrated phase shifter networks within the particular quadrant selected by the FUNCTION Selector. The Phase Dial is calibrated from -6° to $+96^{\circ}$ in 0.5° graduations. Mechanical positioning of this Dial on its shaft is critical and for this reason, should it be necessary to repair or replace, the procedure under Phase Dial Alignment should be followed.

OVERLOAD Indicator

The lamp marked OVERLOAD is turned on whenever a prescribed signal level is exceeded. This indication warns of impending amplifier overload and the attendant inaccuracies which will occur when larger saturating signals are present. The OVERLOAD Indicator is factory set to turn on at 11x full scale. (The instrument will function within its specified accuracy up to and including a 10x overload).

Meter

The Meter is a zero center low stiction microammeter calibrated to read the RMS value of a sinewave. For all voltmeter readings, the pointer deflects to the right. For phase-sensitive measurements, the meter deflection may be to the left or right. It has a calibrated zero center 3-0-3 and 10-0-10 with mirror backing for more precise readability.

CAUTION: By its nature, the instrument is required to handle inputs considerably in excess of its full scale reading. Although an extreme overload capability has been designed in, discretion should be used to avoid application of signals in a manner which will drive the needle hard against the stops. Therefore, always approach a measurement from the least sensitive position and return to this position before making circuit adjustment. This approach will avoid any damage, which may occur to the meter.

Input Terminals

In the Model 214A, five terminals are provided at the front panel for connection to external test circuits. Terminals for both the signal and reference inputs are colored black for circuit ground and colored red for the high side of the input.

In the Model 214B, the REF input terminals are colored red and black which indicates polarity with respect to the SIG terminals (i.e., red is in-phase with red, and black is in-phase with black). See below for Model 214C.

These posts are on standard 3/4" spacing and will accommodate banana plugs, wire, or alligator clips.

CAUTION: Maximum signal input must not exceed 300V RMS and maximum reference input must not exceed 200V. Higher voltages will break down the input capacitors in the instrument. (See Specifications, Section I)

A third, all metallic, chassis ground termination is provided at the SIG input for connecting the circuit ground (the Black plastic one) to chassis ground. A

link is provided between these terminals to allow maximum flexibility of connections. The link is provided to permit grounding at the input terminals or to a remote point in measuring setup. Great care should be given to grounding methods used to avoid ground loops and stray fields. The instrument will not read properly if the input is not grounded.

The following Applies to Model 214C Instruments Only:

The Model 214C instruments are characterized by the inclusion of a Signal Isolation Transformer with facility for switching the transformer in or out of the circuit. The items listed here exist on the Model 214C front panel only.

INPUT Selector Switch - The Input Selector Switch is a slide switch which removes the input transformer from the input circuit in the DIR position allowing for single ended direct coupled inputs. In the TRANS position, floated inputs or differential inputs, as well as single ended isolated inputs, may be fed into the Signal Channel.

NOTE: In order to provide as wide a frequency range as possible and avoid any degradation, a blocking capacitor has not been included in the Transformer Mode. In the event that signals containing DC are to be injected in the Transformer Mode, a large blocking capacitor should be used externally. Without a blocking capacitor, both high and low frequency transformers have an amplitude frequency response which is virtually flat down to 10Hz. The addition of a 2uf blocking capacitor deteriorates low frequency performance to approx. a +1% error at 57Hz and 180Hz for the low and high frequency transformers respectively. This error increases as a function of frequency squared at lower frequencies. The deterioration of performance of the high frequency transformer is of little consequence as this transformer is not normally used below 2.5KHz.

There is no consequential phase error in either low or high frequency transformer at 50Hz or 2.5KHz, respectively. This capacitor should be inserted in series with the high side of the transformer.

SIG Input Terminals - Four SIG Input Terminals are provided on the front panel of the Model 214C which allow flexibility for Direct and Transformer inputs, It should be noted that

the center terminal is common to both Direct and Transformer inputs and is high for Direct inputs and low for Transformer inputs.

The metal binding post as on the Model 214A and 214B instruments is chassis ground.

Fuse - This fuse is a special fuse (1/16A Slo-Blo type, must be BUSS type MDL) is located on the front panel. It is provided as a protection for the Signal Input Transformer(s) in the event that voltages in excess of the rating of the transformer(s) or excessive DC currents are inadvertently applied. A spare is also located on the front panel. Note that the voltage rating of the low frequency Signal Isolation Transformer (TM40) is 0.75f (where f is frequency of operation) 300V max. for the high frequency transformer (TM41). Special attenuating circuits are used in the instrument to permit full rating. For more details, see Section IV, "Isolation Transformers."

CAUTION: IF IT IS DESIRED TO APPLY A LOW FREQUENCY, HIGH VOLTAGE SIGNAL (i.e. 60Hz LINE VOLTAGE) IN THE TRANSFORMER MODE THE FREQUENCY SWITCH SHOULD BE PLACED IN THE LOW FREQUENCY POSITION PRIOR TO THE APPLICATION OF THE VOLTAGE, OR CONVERSELY, THE LOW FREQUENCY, HIGH LEVEL VOLTAGE SHOULD BE REMOVED BEFORE THE FREQUENCY SWITCH IS CHANGED TO A HIGHER FREQUENCY. THIS IS NECESSARY TO INSURE THAT THE ALTERNATE OR LOW FREQUENCY ATTENUATOR IS SWITCHED INTO THE CIRCUIT TO PROVIDE THE ATTENUATION NECESSARY TO PREVENT DAMAGE TO THE TRANSFORMER. (See Frequency Change, Section IV, Pages 4.7 and 4.8, for discussion of the alternate or low frequency attenuator.)

Plug the instrument into the proper power source. Turn the FREQUENCY Selector to any desired frequency. This will turn the instrument on, lighting the meter face. Allow the instrument to warm up for a short period (3 to 5 minutes) for stable operation.

CAUTION: Before making phase or voltage measurements, review the section on grounding techniques in the Application Notes appended hereto.

To Measure Voltage

Set the RANGE Selector to the appropriate scale and the FUNCTION Selector to the appropriate position. Connect the voltage to be measured to the SIGnal input terminals and read the voltage from either the 0-10 or 0-3 volts scales using the proper scale factor as determined by the RANGE Selector position.

With the FUNCTION Selector in the TOTAL Position, the voltmeter operates as a standard AC Voltmeter. This reads the total vector voltage at any frequency including all harmonic effects. With the FUNCTION Selector in the FUND position, the Model 214 will read only the fundamental voltage within the range of the filter chosen by the FREQUENCY Selector.

Notice that with no input to the instrument (terminals not shorted), the meter deflects on the low ranges. This condition is normal and represents a true measurement of stray fields capacitively coupled to the input. Shielding the input will reduce this deflection to a minimum level. Measurements made on high impedance circuits require that special attention be paid to capacitive as well as inductive pickup.

Twisted and/or shielded cable will reduce the effect through the cable capacity could serve to load the source. Care must be taken where possible to insure that ground loops do not exist by virtue of the signal and reference grounds being connected. These loops can result in erroneous readings. (Refer to the Application Notes appended hereto.)

* The minimum input level may not be sufficient to cause a red line reading on the meter; however, the instrument will still operate within specification when the reference level control is set to as near red line as possible.

Phase Angle Measurements - With Calibrated Phase Shifter

1. Set the FREQUENCY Selector to the proper frequency of the signal to be measured.

2. Switch the FUNCTION Selector to the REF ADJ Position.

3.* Inject the reference signal into the REF terminals and adjust the HI-LO Switch and the Reference Level Control to cause the meter to read a value as indicated by the red mark on the meter scale.

4. Switch the RANGE Selector to a suitable position and inject the signal to be measured into the proper terminals.

5. Set the Phase Dial to 0°.

6. Switch the FUNCTION Selector to a PAV Position (phase sensitive) which will cause the meter to read to the right.

7. Turn the Phase Dial to cause the meter to read near maximum. This step is to provide a coarse deflection of the phase angle.

8. Switch the FUNCTION Selector 90°.

9. Turn the Phase Dial until the meter reads 0.

10. Switch the RANGE Switch to two ranges more sensitive (e.g., if Step 9 is performed on the 100mv Range, then this should be performed on the 10mv Range position).

11. Adjust the Phase Dial more precisely for a null on the meter.

12. Switch the FUNCTION Selector to a position (0, 90, 180, 270°) which gives a meter deflection to the right.

13. The phase angle is then the sum of the FUNCTION Selector angle plus the Phase Dial angle. This rule eliminates the possibility of ambiguity. In the event the user makes a measurement with a deflection to the left in Step 12, add or subtract 180° from the sum of the quadrant and Phase Angle Dial.

Measurements of In-Phase (0°) and Quadrature (90°) Components

1. With reference level properly set, place FUNCTION Selector in the 0° position. Set the Phase Dial to 0°.

2. The meter now reads the in-phase component of a signal. This is also E cos θ where θ is the angle between the reference and signal.

3. Switch the FUNCTION Selector to 90°. The meter now reads the quadrature component or E sin θ.

   In general, one of these components is usually much smaller than the other and for greater accuracy, it is convenient to change the range of the instrument. This can be done until the OVERLOAD Lamp lights thereby warning of an impending overload condition. This light indicates that total signal exceeds eleven (11) times the full scale value. Measurements can be made for overloads up to 10 times full scale (see Page 2.11). Measurements under all these conditions will be most accurate if the zeroing process described in the Application Notes is followed.

Measurements Under Overloaded Conditions

Measurements under overloaded conditions can be made where it is desired to increase the null capability or to make the small quadrature signal level measurements. As stated previously, the signals levels in the Signal Channel may be 10 x the full scale reading as indicated by the RANGE Switch setting. Under some special conditions, these signals may exceed this 10 x specification by small amounts without overloading the amplifiers in the signal circuits. These signals, however, should never be increased beyond the level which will cause the overload indicator to light.

Accurate measurement of phase angles can also be made using the E cos θ or E sin θ characteristic. Voltage measurements are made from the in-phase (0°) or quadrature (90°) component of the fundamental signal (FUND Position). The quotient will then be the cosine, or sine, or tangent of the unknown phase angle. Trigonometric

tables, slide rule, or graphs included in the appended Application Notes are suitable for converting to degrees. The accuracy achievable using this technique depends upon the procedure, and for that reason, it is suggested the Application Notes be reviewed before using this method.

Frequently measurements are made where the signal level does not lend itself to exact 10 x overload settings (i.e., 1.5V on the 3V Range which will be only a 5 x overload on the .3V Range or 15 x overload on the .1V Range). In order to extend the overload capability of the Model 214, the Range Vernier may be used. By adjusting the Vernier to cause a full scale reading, the full 10 x overload may now be realized. The following is an illustration of this function.

With a 15mv signal input and the RANGE Switch in the 10mv position, the Vernier may be adjusted to cause the meter to read full scale. The FUNCTION Selector is now rotated to read a phase sensitive null. The RANGE Switch may now be set to the 1mv position which increases the null sensitivity by 10:1. This condition will not overload the instrument's amplifiers.

The above illustration is typical and is repeatable on all ranges with the following exception. A signal in excess of 3V is applied in the 3V Range and is reset to read full scale. When the RANGE Switch is rotated to the .3V range, the input amplifier will be overloaded (due to a 3V maximum capability) and an erroneous reading will occur.

SECTION III

THEORY OF OPERATION

INTRODUCTION

The schematic and block diagram of Figures 3.1 and 3.2 will serve to illustrate the principles of operation of the Phase Angle Voltmeter. The Phase Angle Voltmeter is a multi-function instrument and the following will describe each of these functions.

VOLTMETER

When operating as a total and fundamental voltmeter, the instrument uses only the Signal Channel circuitry. The Signal Amplifier, in conjunction with the Range Attenuators, functions in a similar manner to a good quality AC Electronic Voltmeter. The signals applied to the input are amplified and fed to the meter rectifier circuit and indicated on the meter.

As a Fundamental Voltmeter, a harmonic filter is switched into the circuit and the meter will read only those frequencies within the pass band of the filter. See Figure 3.6 for filter characteristics.

As a Phase Angle Voltmeter, the Reference Channel is activated. The reference signal is amplified and phase shifted by the reference circuitry. The signal serves to gate the demodulator portion of the meter circuit. The relationship of this gating voltage to the signal being measured will determine the magnitude and the polarity indicated on the meter.

For those signals which are in-phase, a signal of maximum amplitude will be indicated and for those signals which are 90° out-of-phase (in Quadrature) a minimum signal will be read. Where the instrument is being used to read quadrature signals, these signals may exceed the indicated range by up to 10 x without overloading the signal amplifier circuits. This capability provides a means for much more accurate measurements of quadrature voltages and computation of phase angles.

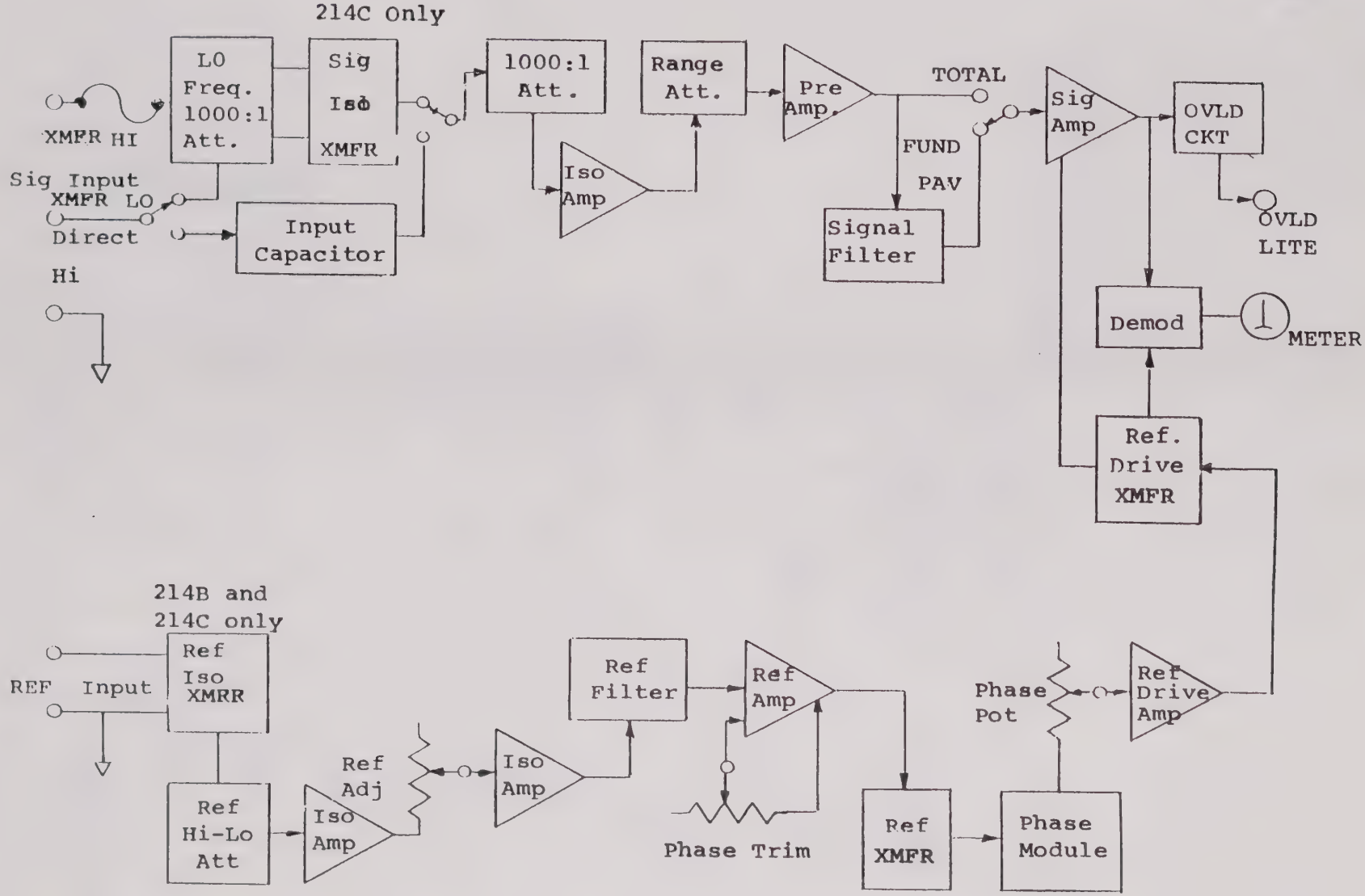


Figure 3.1
Page 3.2

MODEL 214 - PHASE ANGLE VOLTMETER
BLOCK DIAGRAM

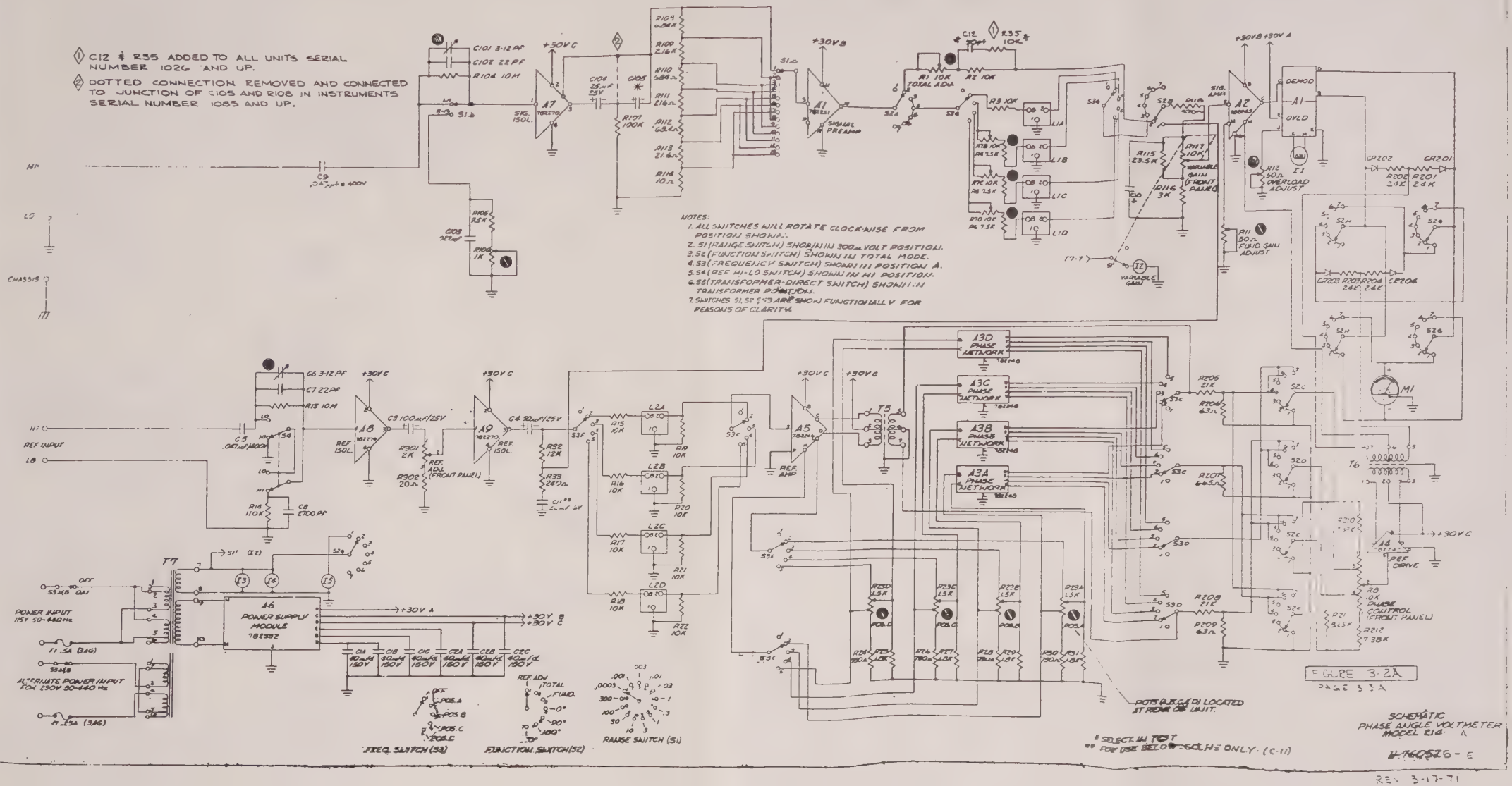

◊1 C12 & R35 ADDED TO ALL UNITS SERIAL NUMBER 1026 AND UP.
◊2 DOTTED CONNECTION REMOVED AND CONNECTED TO JUNCTION OF C105 AND R108 IN INSTRUMENTS SERIAL NUMBER 1085 AND UP.
NOTES:
1. ALL SWITCHES WILL ROTATE CLOCKWISE FROM POSITION SHOWN.
2. S1 (RANGE SWITCH) SHOWN IN 300 m VOLT POSITION.
3. S2 (FUNCTION SWITCH) SHOWN IN TOTAL MODE.
4. S3 (FREQUENCY SWITCH) SHOWN IN POSITION A.
5. S4 (REF HI-LO SWITCH) SHOWN IN HI POSITION.
6. S5 (TRANSFORMER-DIRECT SWITCH) SHOWN IN TRANSFORMER POSITION.
7. SWITCHES S1, S2 & S3 ARE SHOWN FUNCTIONALLY FOR REASONS OF CLARITY.
HI
LO
CHASSIS
REF INPUT
POWER INPUT 115V 50-440Hz
ALTERNATE POWER INPUT FOR 230V 50-440 Hz
+30V A
+30V B
+30V C
A1 SIGNAL PREAMP
A2 FINAL AMP
A3A PHASE NETWORK
A3B PHASE NETWORK
A3C PHASE NETWORK
A3D PHASE NETWORK
A5 REF AMP
A6 POWER SUPPLY MODULE 782332
A7
A8
A9
REF ADJ (FRONT PANEL)
OVERLOAD ADJUST
FINAL GAIN ADJUST
VARIABLE GAIN (FRONT PANEL)
PHASE CONTROL (FRONT PANEL)
REF DRIVE
FREQ. SWITCH (S3)
FUNCTION SWITCH (S2)
RANGE SWITCH (S1)
POTS SHOWN ON LOCI ARE LOCATED AT REAR OF UNIT.
* SELECT IN TEST
** FOR USE BELOW 50 CPS Hz ONLY. (C-11)

FIGURE 3-2A

PAGE 3-3A

SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 814 A

~~A-760526~~ - E

REV. 3-17-71

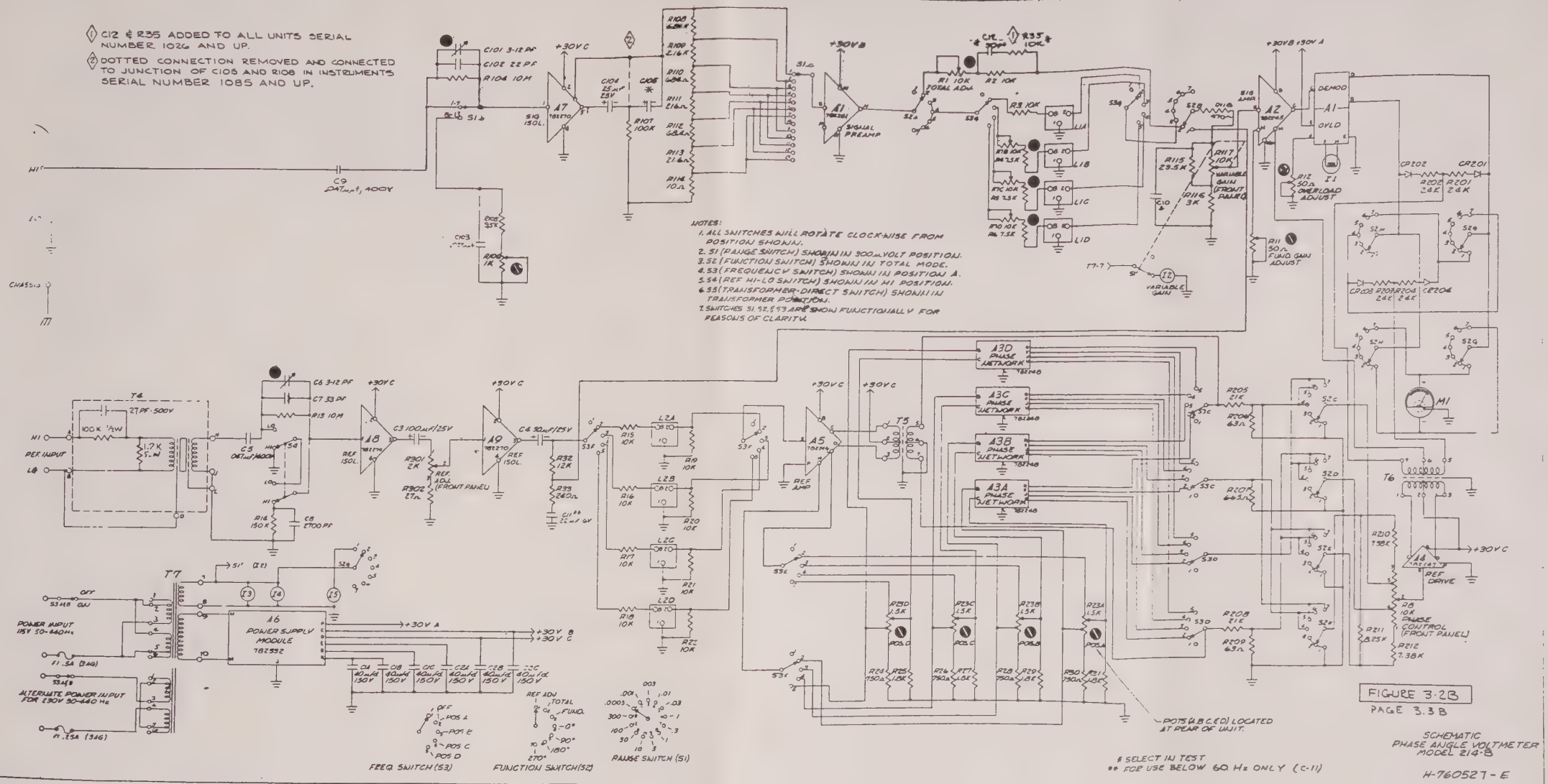

◇1 C12 & R35 ADDED TO ALL UNITS SERIAL NUMBER 1026 AND UP.
◇2 DOTTED CONNECTION REMOVED AND CONNECTED TO JUNCTION OF C105 AND R108 IN INSTRUMENTS SERIAL NUMBER 1085 AND UP.
NOTES:
1. ALL SWITCHES WILL ROTATE CLOCKWISE FROM POSITION SHOWN.
2. S1 (RANGE SWITCH) SHOWN IN 300 m VOLT POSITION.
3. S2 (FUNCTION SWITCH) SHOWN IN TOTAL MODE.
4. S3 (FREQUENCY SWITCH) SHOWN IN POSITION A.
5. S4 (REF HI-LO SWITCH) SHOWN IN HI POSITION.
6. S5 (TRANSFORMER-DIRECT SWITCH) SHOWN IN TRANSFORMER POSITION.
7. SWITCHES S1, S2, & S3 ARE SHOWN FUNCTIONALLY FOR REASONS OF CLARITY.
A1 SIGNAL PREAMP
A2 OVLD
A3A PHASE NETWORK
A3B PHASE NETWORK
A3C PHASE NETWORK
A3D PHASE NETWORK
A5 REF AMP
A6 POWER SUPPLY MODULE 782332
A7 782270
A8 REF DRIVE
A9 782270
POWER INPUT 115V 50-440Hz
ALTERNATE POWER INPUT FOR 230V 50-440 Hz
FREQ SWITCH (S3)
FUNCTION SWITCH (S2)
RANGE SWITCH (S1)
POTS (A,B,C,D) LOCATED AT REAR OF UNIT.
* SELECT IN TEST
** FOR USE BELOW 60 Hz ONLY (C-11)

FIGURE 3-2B
PAGE 3.3B

SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 214-B

H-760527-E

REV 3-17-71

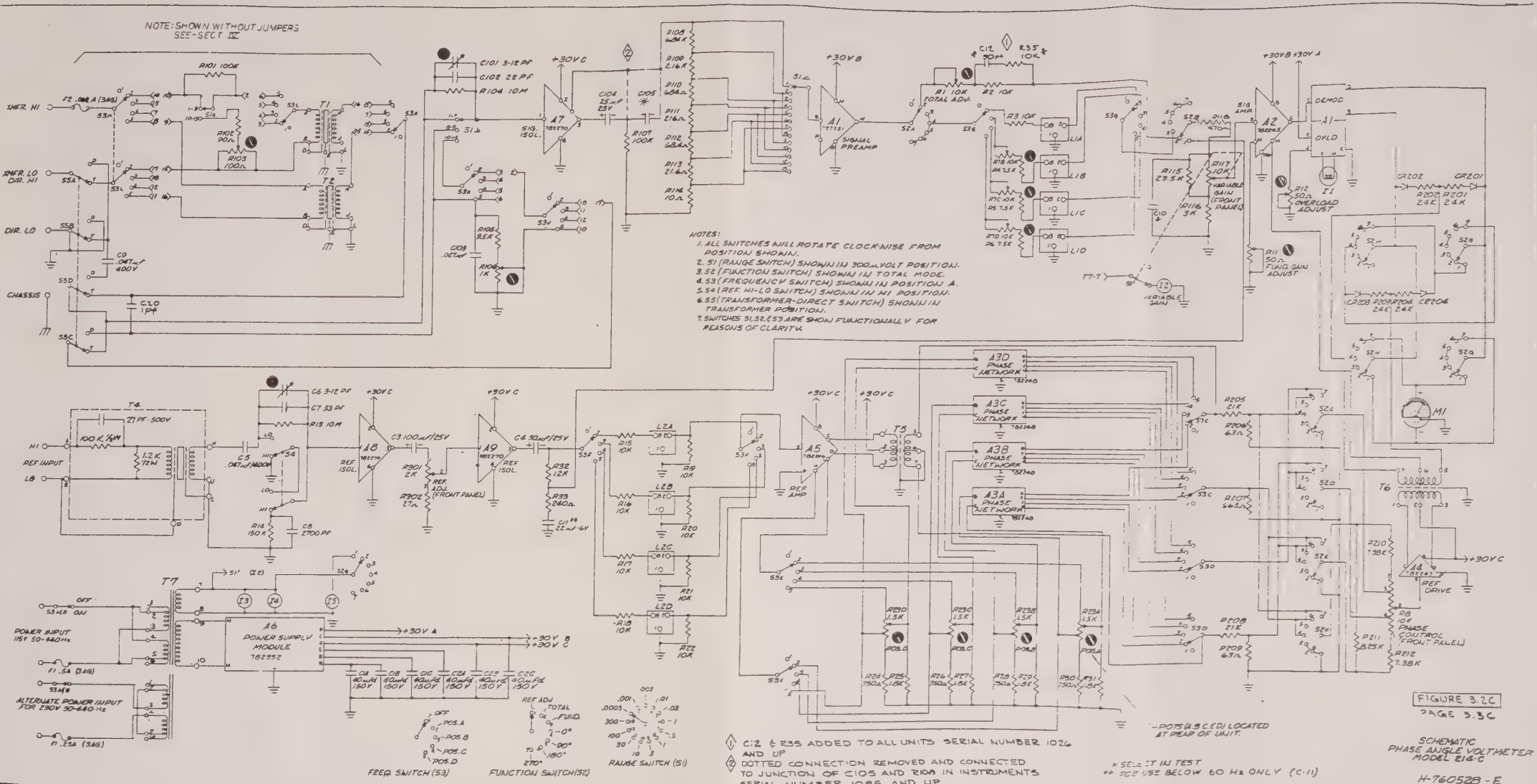
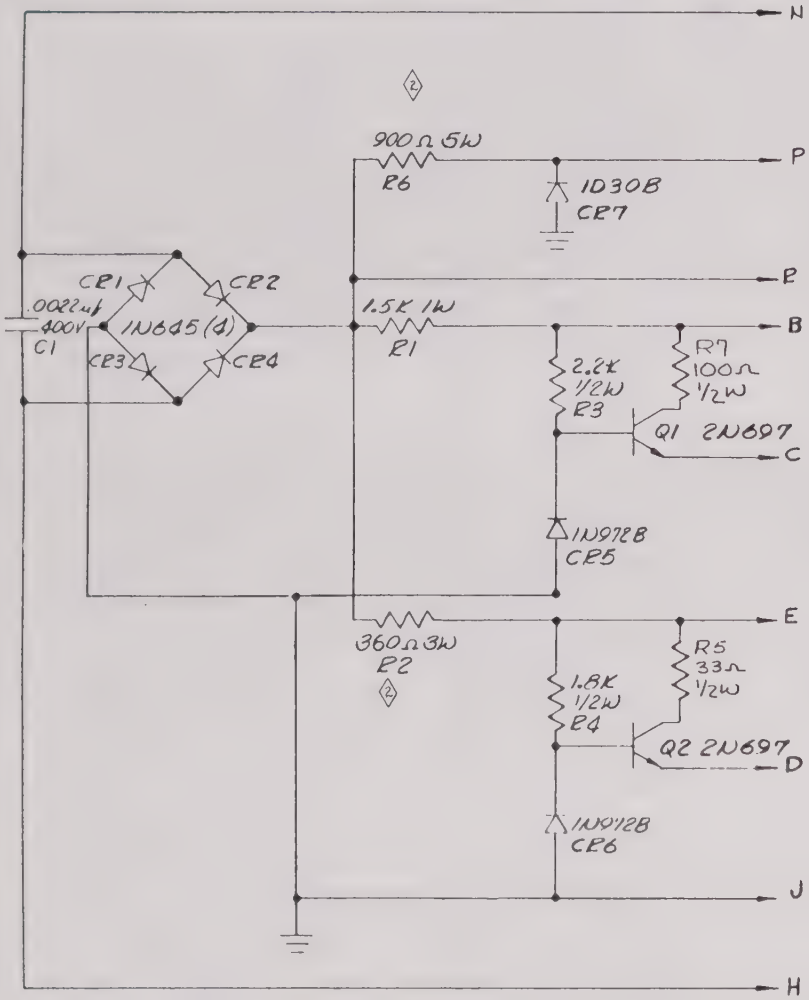

NOTE: SHOWN WITHOUT JUMPERS SEE-SECT IV
NOTES:
1. ALL SWITCHES WILL ROTATE CLOCKWISE FROM POSITION SHOWN.
2. S1 (RANGE SWITCH) SHOWN IN 300 m VOLT POSITION.
3. S2 (FUNCTION SWITCH) SHOWN IN TOTAL MODE.
4. S3 (FREQUENCY SWITCH) SHOWN IN POSITION A.
5. S4 (REF HI-LO SWITCH) SHOWN IN HI POSITION.
6. S5 (TRANSFORMER-DIRECT SWITCH) SHOWN IN TRANSFORMER POSITION.
7. SWITCHES S1, S2, & S3 ARE SHOW FUNCTIONALLY FOR REASONS OF CLARITY.
A1 SIGNAL PREAMP
A2 AMP
A3A PHASE NETWORK
A3B PHASE NETWORK
A3C PHASE NETWORK
A3D PHASE NETWORK
A4 REF DRIVE
A5 REF AMP
A6 POWER SUPPLY MODULE 702332
A7 SIG. ISOL.
A8 REF ISOL.
A9 REF ISOL.
T1
T2
T3
T4
T5
T6
T7
M1
POWER INPUT 115V 50-440 Hz
ALTERNATE POWER INPUT FOR 230V 50-440 Hz
FREQ SWITCH (S3)
FUNCTION SWITCH (S2)
RANGE SWITCH (S1)
1 C12 & R35 ADDED TO ALL UNITS SERIAL NUMBER 1026 AND UP
2 DOTTED CONNECTION REMOVED AND CONNECTED TO JUNCTION OF C105 AND R104 IN INSTRUMENTS SERIAL NUMBER 1085 AND UP.
* SELECT IN TEST
** FOR 1 HZ BELOW 60 Hz ONLY (C-11)
-POTS (A,B,C,D) LOCATED AT REAR OF UNIT.

FIGURE 3.2C
PAGE 3.3C

SCHEMATIC
PHASE ANGLE VOLTMETER
MODEL 214-C

H-760528-E

REV 3-17-71



NOTE:-
R5 & R7 INCLUDED IN ALL POWER SUPPLIES FOLLOWING AND INCLUDING SERIAL NUMBER 126 (SERIAL NUMBER IS LOCATED ON LOWER LEFT CORNER OF PRINTED CIRCUIT CARD.)

2 CHANGED ON ALL UNITS SERIAL NO. 1040 AND ABOVE.

R2 WAS 430Ω, 2W and R6 WAS 910Ω, 2W
ON ALL UNITS BELOW SERIAL NO. 1040.

Figure 3.3
Schematic, Power Supply

Revised,
7/20/66

SIGNAL INPUT ATTENUATOR

The amplifiers of the Model 214 always operate with the same basic sensitivity (300uv). This requires attenuators for reducing higher level voltages to this range. The input attenuator actually consists of two separate voltage divider networks. The first provides a 1000:1 reduction for voltages one volt and above. The second provides six attenuator ranges from 3:1 to 1000:1. This latter attenuator provides attenuation for signals up to and including 300mv and is added to the attenuation of the 1000:1 divider for signals between 3 volts and 300 volts.

At low frequencies, the 1000:1 attenuator ratio is determined soley by the resistors employed. At higher frequencies, capacitive compensation is necessary to compensate for circuit strays. This converts the attenuator to a capacitive divider at high frequencies. The crossover from resistive to capacitive attenuation occurs at approximately 600Hz. This attenuator when properly adjusted not only provides proper attenuation at both high and low frequencies but also has essentially zero phase shift over the rated frequency range. See Calibration Procedure, Section VI, for proper alignment.

AMPLIFIERS

The amplifiers used in the Model 214 Phase Angle Voltmeter are plug-in, silicon transistorized modules. All designs are based on the use of components well below maximum manufacturer's ratings to insure long-life and trouble-free operation. These modules are factory sealed, and in the event of failure, should be replaced as a unit. This seal should not be broken as this will void the North Atlantic Warranty. The individual amplifiers are described in the following paragraphs.

Isolation Amplifiers (Not Plug-In) - There are three isolation amplifier modules (A7, A8, and A9) located on the underside of the chassis. These modules contain very similar circuitry, each being modified slightly for a specific function. The basic function of this amplifier is to provide an accurate gain of unity, a high input impedance to the circuitry preceding it in order to prevent loading, and a low output impedance to the

circuits which follow. The design of this amplifier is based on techniques using low noise field effect transistors.

Signal Pre-Amplifier - The Signal Pre-Amplifier is contained within the A1 Module, NAI #782251. This Amplifier provides a stable gain of 10 which is necessary for the 300uv sensitivity of the instrument. Large amounts of negative feedback are used so that its gain is controlled solely by stable precision resistors internal to the module. Its design is such that it provides a wide band frequency response with minimal phase shift and low noise.

Signal Amplifier - The Signal Amplifier (A2, NAI #782245) is a circuit designed to have a very high gain bandwidth product resulting in a low phase shift and high power gain. Its output drives the meter demodulator circuit. Large amounts of negative current feedback are used to eliminate the effects of diode non-linearities. The meter demodulator circuit is located partly within the A1 Module and partly on the FUNCTION Switch.

The Demodulator's phase-sensitive operation (see Figure 3.4) can be likened to that of a set of commutating switches. The reference signal alternately connects one side of the meter to ground through resistor R11 and then the other end on the reverse cycle of the reference. The signal is, therefore, synchronously rectified through the meter movement. When the reference and signal are in-phase (Figure 3.4a) the average value will be a maximum and the meter will read a maximum. When the signals are 90° apart (Figure 3.4b) the average will be zero and no reading will result. The equation governing this is:

$$I_{Meter\ (avg)} = K E \cos \theta$$

Where K = proportionality constant
E = RMS of signal
θ = angle between signal and reference.

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Demodulator saturation effects will limit this characteristic equation to the designed levels for the instrument. Under special conditions, such as are described in the appended Application Notes, the reference level is increased to improve accuracy for high signal levels. Measurements at the quadrature null point ($\theta = 90^{o}$) are relatively unaffected by saturation.

The response of the phase sensitive detector is limited to signals at the reference frequency as well as to odd order harmonics. Response for this type detector to odd order harmonics will never be greater (usually less depending upon phase angle) than the fundamental response multiplied by a factor 1/n where n is the order of the harmonic. Where a Signal Channel filter is used, there is, of course, essentially no response to harmonics in the signals.

All other frequencies are rejected except for signals very near to the reference frequency and its odd harmonics. Here, the meter movement will oscillate between 0 degrees in-phase and 180 degrees out-of-phase and at a frequency proportional to the difference between the input frequency and the fundamental or third harmonic of the reference signal. Response of this nature is limited to frequency differences of about 5Hz (meter pass band).

The effect of reference harmonics is much less important than that of signal harmonics because the harmonic content can never do more than shift the point at which the diodes start to conduct. Expressed otherwise, there is an equivalent error in degrees which results from harmonics in the Reference Channel. For measurements using the phase shifter, the error can be removed by trimming. For measurements using E cos θ characteristic, the effect is small because the meter reading as a function of current integrated over an entire cycle and the small error produced by distortion has a correspondingly small effect on the total current.

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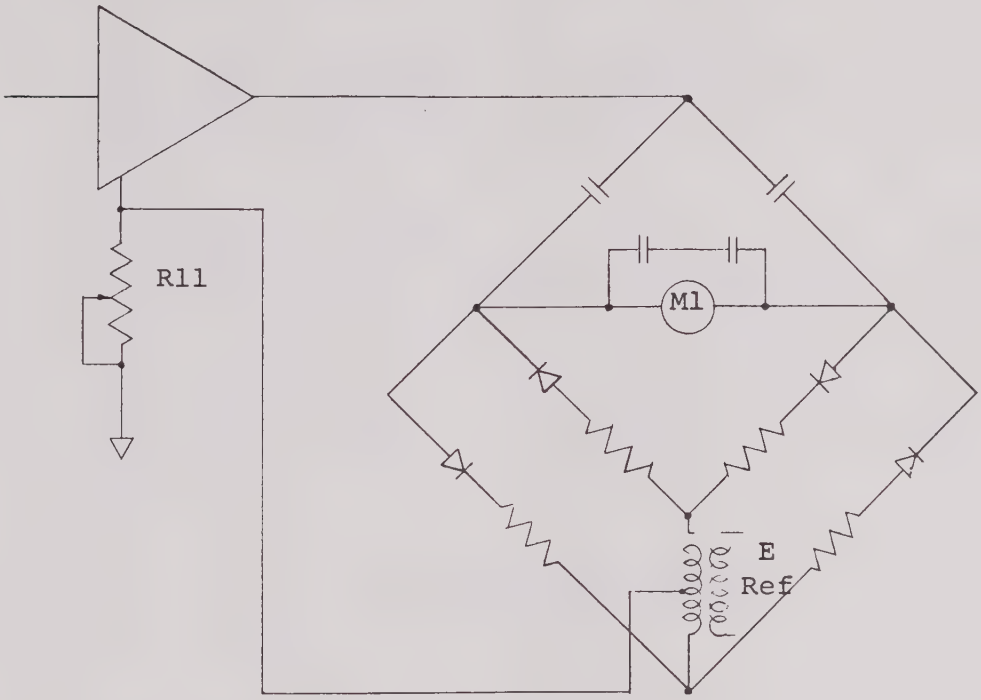
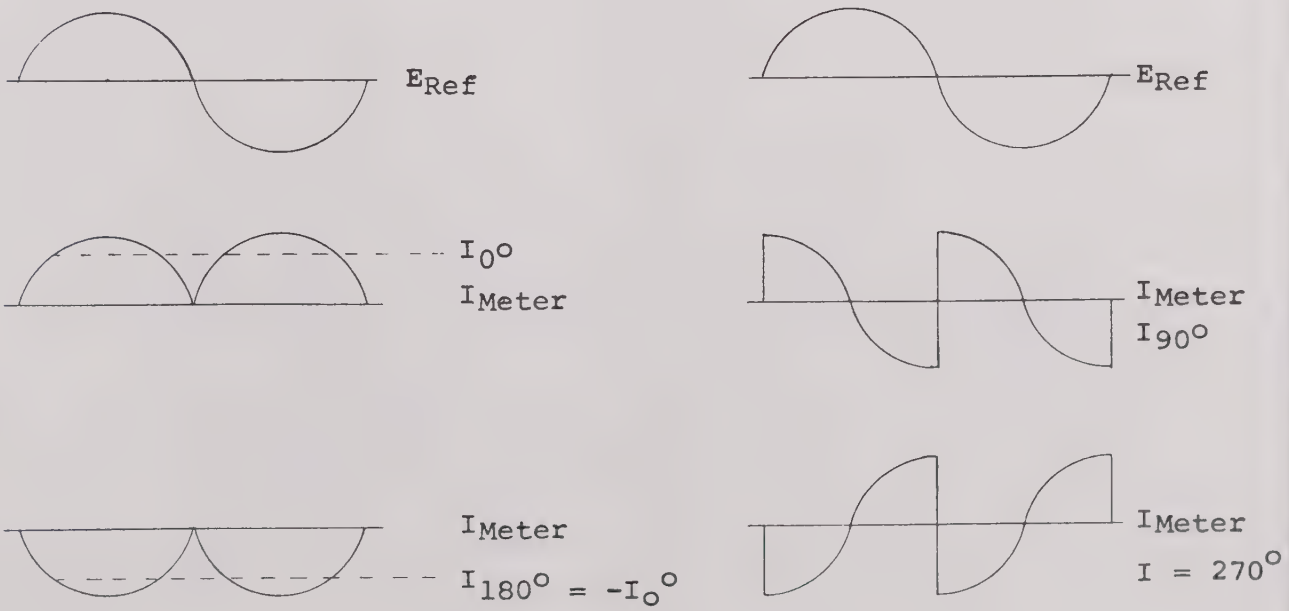
SIMPLIFIED PHASE SENSITIVE DEMODULATOR





IN PHASE (0°/180°)
(A)

QUADRATURE (90°/270°)
(B)

Figure 3.4

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When used as a conventional voltmeter, the phase-sensitive rectifier is switched to a full wave rectifier configuration. Operation is identical to that of a full wave bridge power supply in which the meter movement acts as the load.

Effects of Distortion - The current through the meter in the latter circuit is proportional to the average value of the voltage waveform applied. Calibration of the meter in RMS is based on a ratio between the average and effective values of a true sinesoidal voltage. Deviation from a true sinewave may cause errors in the meter indication. Table I lists the range of possible errors due to the 2nd and 3rd harmonic distortion.

TABLE I - Errors Due to Harmonics in a Typical Average Detector

Harmonic Order	Harmonic Content	Error
2nd	10%	Nil
2nd	20%	0 to +2%
2nd	50%	0 to +10%
3rd	10%	-4% to +4%
3rd	20%	-6% to +8%
3rd	50%	-10% to +16%

The signal also drives the Overload Detector Circuit. The Overload Detector Circuit is designed to operate as a switch. When the signal level out of the Signal Amplifier Module (A2) exceeds a level of approximately 11 x full scale, the circuit will switch turning on the OVERLOAD indicator. The signal amplifiers will operate up to and including a 10 x overload. The indicator is set to ignite above this level and ordinarily measurements may not be made as long as the indicator is lit. The amplifiers, however, have the capability of operating with larger signals without distorting.

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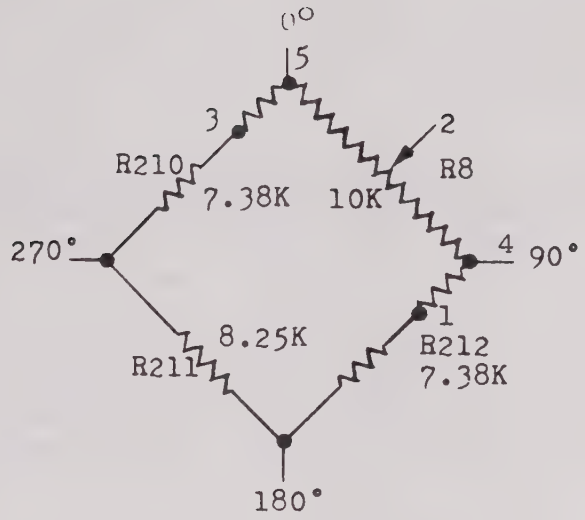
A3, Phase Module (PM10) - The A3 modules contain the Phase Shift circuitry required to generate the precision phase shifts in the Reference Channel. These modules are supplied for specific frequencies as required by the individual user. They are designed to operate within specification over a ±5% bandwidth of the nominal frequency without readjustment. There may be 1, 2, 3, or 4 of these modules existing in the equipment. An output of 0^{o}, 90^{o}, 180^{o}, and 270^{o} is provided and is selected by the FUNCTION Switch. Angles in any quadrant are determined by connecting the phase potentiometer to any two adjacent points through the FUNCTION Switch. This provides a phase shift capability of 0^{o} to 360^{o} as determined by the FUNCTION Selector setting plus the Phase Dial (phase potentiometer) setting. (See Figure 3.5)

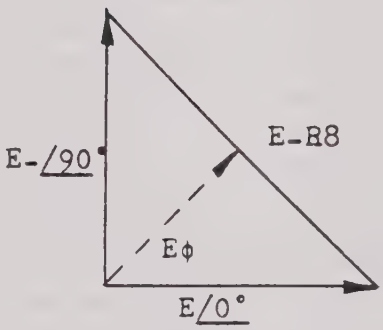
These Phase Modules may be supplied as part of a Frequency Kit or individually. They are identified by either their NAI Part No. (782248-XX) or by their model number (PM10-XXX) followed by the operating frequency.

A4, Reference Drive Module (NAI #782247) - It is the function of this module to accept phase shifted signals from the arm of the phase potentiometer and convert it to a push-pull driving signal, which performs the ultimate operation of gating the demodulator. The amplifier is designed to provide the necessary power gain while maintaining a minimal phase shift.

A5, Reference Amplifier (NAI #782246) - The A5 module is essentially the same as the A4 Reference Drive Amplifier except that its push-pull output is used to drive the phase shift networks. This amplifier has in its feedback network a channel phase control (R23A, B, C, and D) which provides small leading and lagging phase shifts. This control is used to align the phase shifts between the signal and reference channels to 0. It provides this phase shift without the introduction of any phase gradient so that once set at a frequency, it will not vary over a 5% bandwidth.



PHASE SHIFT BRIDGE



$E/\underline{0^\circ} = E/\underline{90^\circ}$

$\theta = \theta \text{ Max } \frac{\text{Tan } \phi}{1 + \text{Tan } \phi}$

ϕ = Electrical Phase Angle

θ = R8 Shaft Angle

VOLTAGE VECTOR AT PHASE POTENTIOMETER

The voltage E-R8 appears across the Phase Potentiometer R8 between the taps, terminals 4 and 5. When $E/\underline{0^\circ}$ is set equal to $E/\underline{90^\circ}$, the electrical angle $E/\underline{\phi}$ is a non-linear function of the potentiometer shaft angle. This is compensated by a non-linear phase dial. This function is described by the equation shown.

The 90° angular rotation is shifted to any quadrant by the four corners of the bridge being rotated to cause the desired quadrant voltage to appear across the potentiometer. This is performed by the function switch.

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A6, Power Supply (NAI #782232), See Schematic, Figure 3.3
This module contains three +30V DC sources. Two of these 30V sources are well regulated, well filtered, and are used individually to supply the Signal and Reference Channels.

The third 30V source is zener regulated and is used to supply the overload circuitry. Note that the filtering for the power supply is accomplished by means of electrolytic capacitors C1 and C2 mounted on the chassis.

FILTERS

The filters used are matched, plug-in low pass types and are supplied in pairs. The filters used in this instrument are supplied as matched pairs. These pairs are identified by the same serial number appearing on both. The serial number is located just beneath the North Atlantic nameplate. In order to insure optimum performance, these filters should always be installed as a matched set. The filters are operated in a restricted portion of the pass band in order to maintain, over this band, the amplitude gradient within the instrument's specifications and to restrict the phase variation. Table II describes all filters available and their usable bands and Figure 3.6 is a typical filter response. Referring to Table II, F_m designates the geometric mean frequency of the usable band. The upper frequency limit is determined by the amplitude vs. frequency characteristic. Lower frequency limit is determined by the amount of rejection of the third harmonic of this frequency.

NOTE: When making phase-sensitive measurements the detector circuit inherently has a high second harmonic rejection (approx. 55DB) and 10DB additional rejection of the third harmonic. This additional harmonic rejection is individually added to the filter rejection when operating in any phase-sensitive mode.

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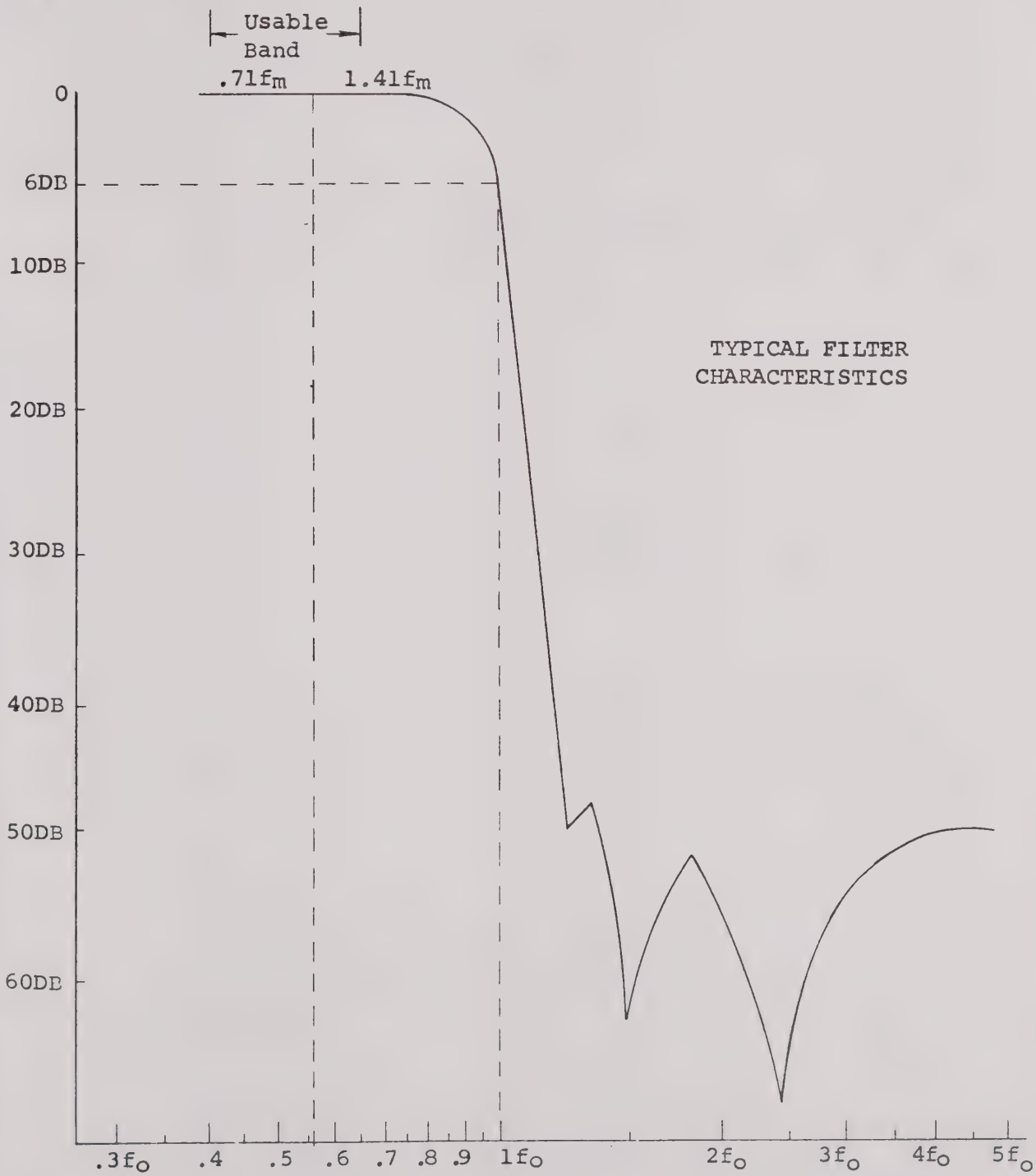

TYPICAL FILTER
CHARACTERISTICS

Figure 3.6

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TABLE II

Model No.	Part No.	Useable Band
FM-21	782334-11	27.5Hz to 55Hz
FM-21	782334-1	55Hz to 110Hz
FM-21	782334-2	110Hz to 220Hz
FM-21	782334-10	265Hz to 530Hz
FM-21	782334-4	525Hz to 1050Hz
FM-21	782334-5	880Hz to 1760Hz
FM-21	782334-6	1760Hz to 3520Hz
FM-21	782334-7	3520Hz to 7040Hz
FM-21	782334-8	7040Hz to 14.1KHz
FM-21	782334-12	14.2KHz to 28.2KHz

Filters may be specified either by NAI Part Nos. or by Model Nos. followed by the operating frequency.

Filter #782830 is a direct replacement for, and may be used interchangeably with, filter #782334-10 for 400Hz applications.

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ISOLATION TRANSFORMER-Model 214B (REF) and 214C (SIG and REF only)
(See Figures 3.7, 3.8, and 3.9)

The Signal Isolation Transformers are designed to operate within a limited band. The low frequency isolation transformer (Model TM40) will operate over a band of from 30Hz to 2.5KHz. The high frequency transformer (Model TM41) will operate over a band of frequencies from 2.5KHz to 20KHz. Frequencies of operation, as specified by the user, will determine whether the low frequency, high frequency, or both transformers will be required. These transformers may be used for isolating signal inputs for both single ended and differential measurements.

The maximum voltage limitation of these transformers is expressed in terms of f where f is the operating frequency. The lower frequency transformer (TM40) is rated at 0.75f up to a maximum of 300V and the high frequency transformer (TM41) is rated at 0.12 f up to 300V maximum. When used in the Model 214C, an additional input attenuator (see Frequency Change Section, Section IV) permits their use over the full rated voltage range of the instrument.

Reference isolation, being much less critical than the signal isolation, requires only a single transformer be used. This transformer (Model TM42) is used on both the Models 214B and 214C.

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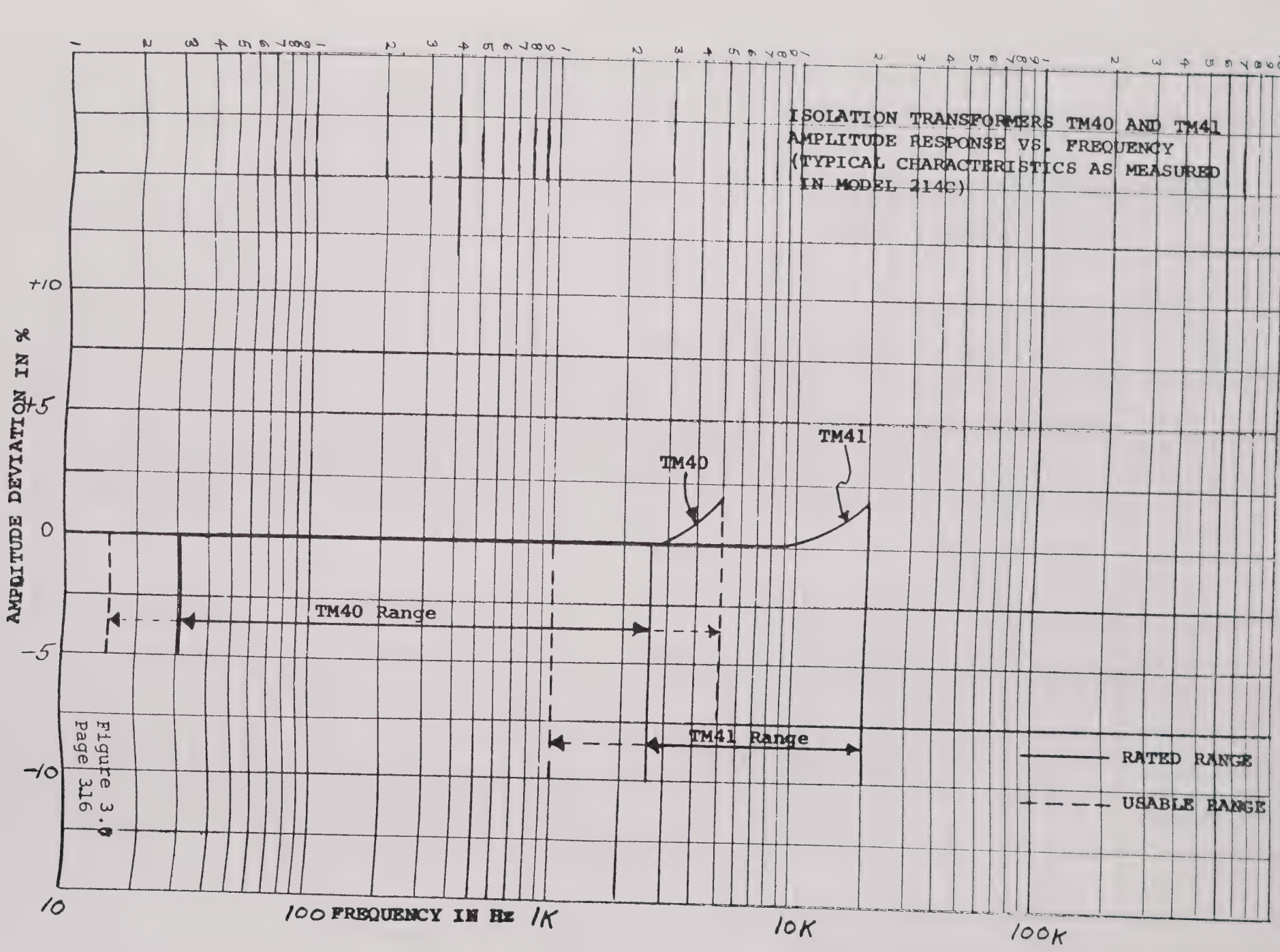

Figure 3.9
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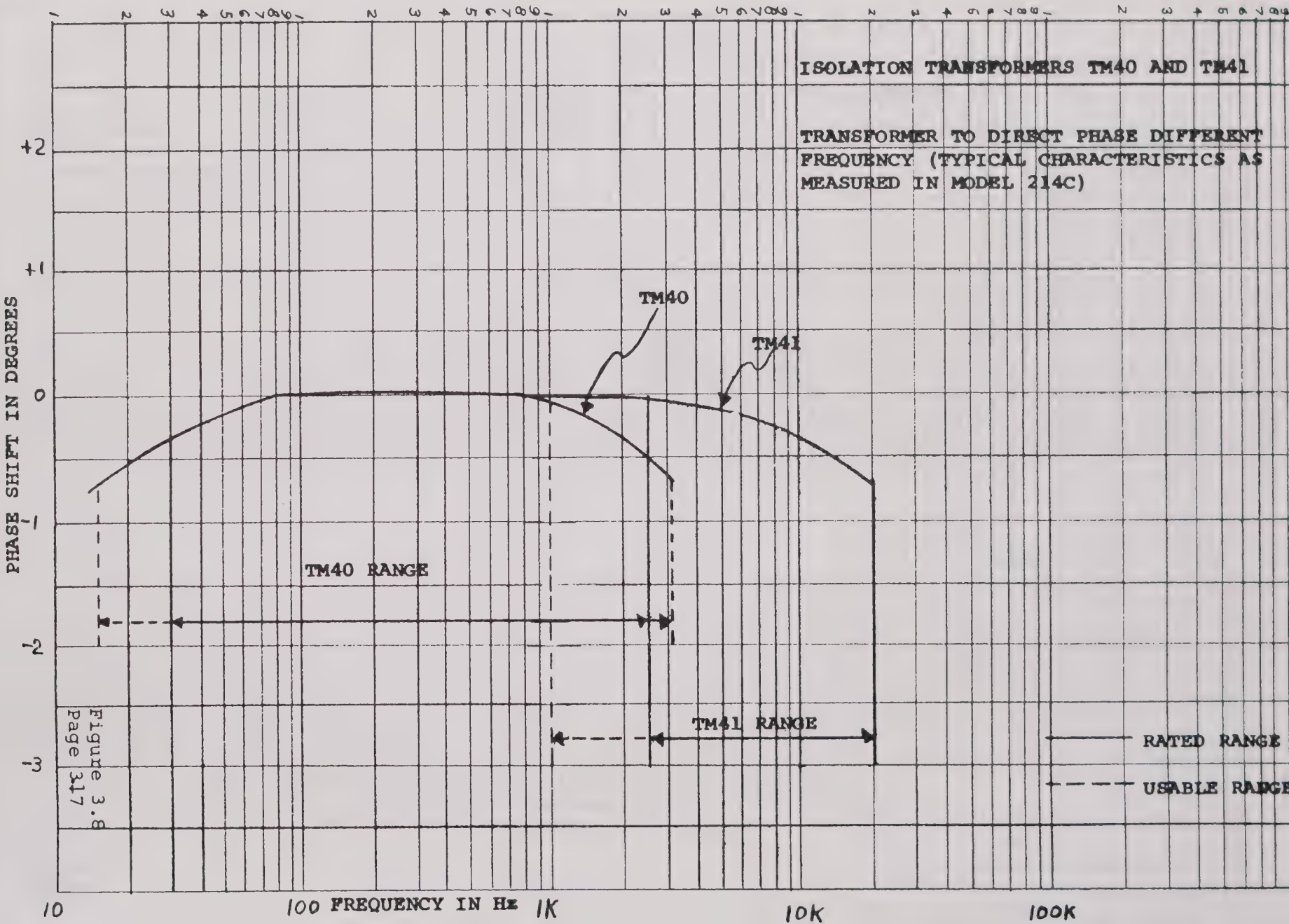

Figure 3.8
Page 3.17

NOTE: For frequencies below 400Hz where the alternate attenuator is used, the Model 214C input impedance is 100KΩ resistive in the 10V to 300V Ranges.

ISOLATION TRANSFORMERS TM40 AND TM41
INPUT IMPEDANCE VS. FREQUENCY
(TYPICAL CHARACTERISTICS AS MEASURED IN MODEL 214C)

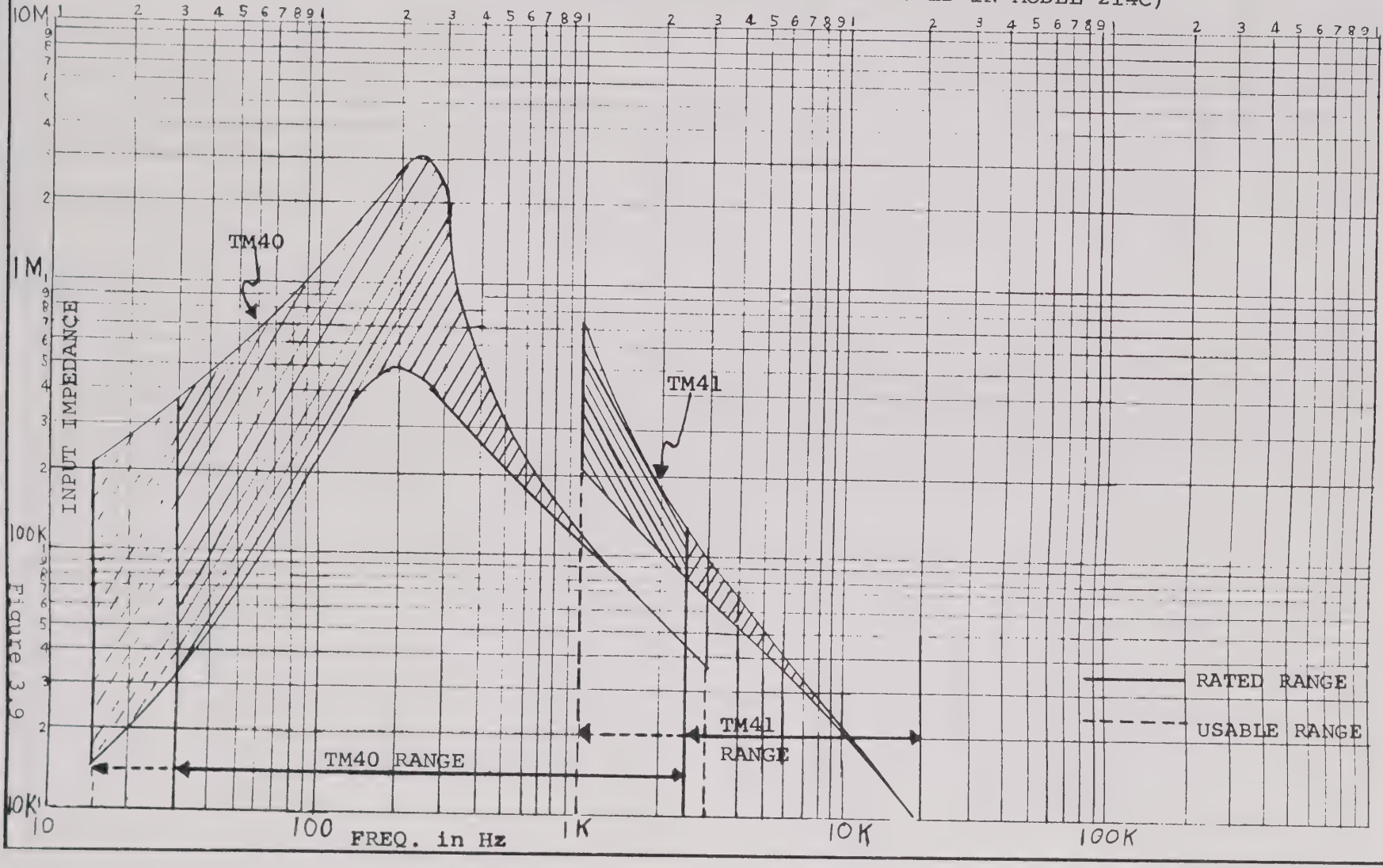

Figure 3.9

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FREQUENCY Switch

The FREQUENCY Switch in the Model 214C only has been constructed so as to provide maximum flexibility in the field. In the event that the frequency of any given channel is to be changed, the jumpers on TB1 and TB2 in the FREQUENCY Switch may be changed to include the proper signal isolation transformer. The instrument as wired at the factory will have these jumpers arranged for the frequencies which are factory installed. Complete instructions for making field modifications are given in Section IV.

NOTE: An adjustable stop is provided on the FREQUENCY Switch to prevent rotation to unused positions in instruments which use less than four channels. It consists of a stop bar clamped to the switch shaft and a fixed stop pin located in the sub-panel. This stop may be readjusted in the following manner.

Remove the bottom cover of the instrument. Loosen the set screw which clamps the stop bar on the switch shaft. (This is clearly accessible from the underside between the front panel and the sub-panel). Rotate the switch to the most clockwise position to be used. Press the stop bar against the stop pin and re-tighten the set screw. The stop will now prevent the switch from rotating beyond the position selected.

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SECTION IV

FREQUENCY MODIFICATION
MODEL 214 PHASE ANGLE VOLTMETER

The Model 214 Phase Angle Voltmeter has been specifically designed to allow the change or addition of frequencies of operation by changing or adding plug-in modules. The following information is a description of the modules and instructions for making these changes or additions.

PLUG-IN MODULE KIT
AND TRANSFORMER GUIDE

	APPLICATION
KM30-Frequency* Consists of: FM 21 - Frequency* Filter (supplied in matched pairs) PM 10 - Frequency* Phase Module Front Panel Decal	For change or addition of frequency in Model 214A, 214B, and 214C.
TM40 - Signal Isolation Transformer	For signal isolation in the Model 214C in the frequency range of 30Hz to 2.5KHz.
TM41 - Signal Isolation Transformer	For signal isolation in the Model 214C in the frequency range of 2.5KHz to 20KHz.

*Actual frequency of operation, i.e., KM30-400Hz

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FREQUENCY MODULE KIT, KM-30 (See Figure 4.1 for Outline)

The Frequency Module Kit, KM-30, consists of:

1 - PM-10 Phase Module
2 - FM-21 Filter (low pass filters supplied in matched pairs. Other FM Series may be used.)
1 - Frequency decal (for frequency identification at FREQUENCY Switch on front panel).
6 - Jumpers, NAI #202823.

NOTE

For frequencies below 60Hz, Capacitor C11 is included in the Kit. This must be installed in the instrument on the underside of the chassis. A pair of terminals is provided for mounting. The jumper across these terminals must be removed and the capacitor soldered in place. The capacitor, being polarized, must be installed with the negative terminal to ground. See Figure 6.2a.

It should also be noted that connectors J3B and J3C for phase modules may be moved within the chassis cutout to provide space, where necessary, to accommodate the various modules of differing sizes. Three sizes are available. Ordinarily, this alteration will not be necessary except for low frequency modules (below 60Hz).

The 214, as factory wired, will accommodate any combination of modules up to a maximum of 4 when the total thickness dimension of these modules does not exceed 6-1/4". See Figure 4.2.

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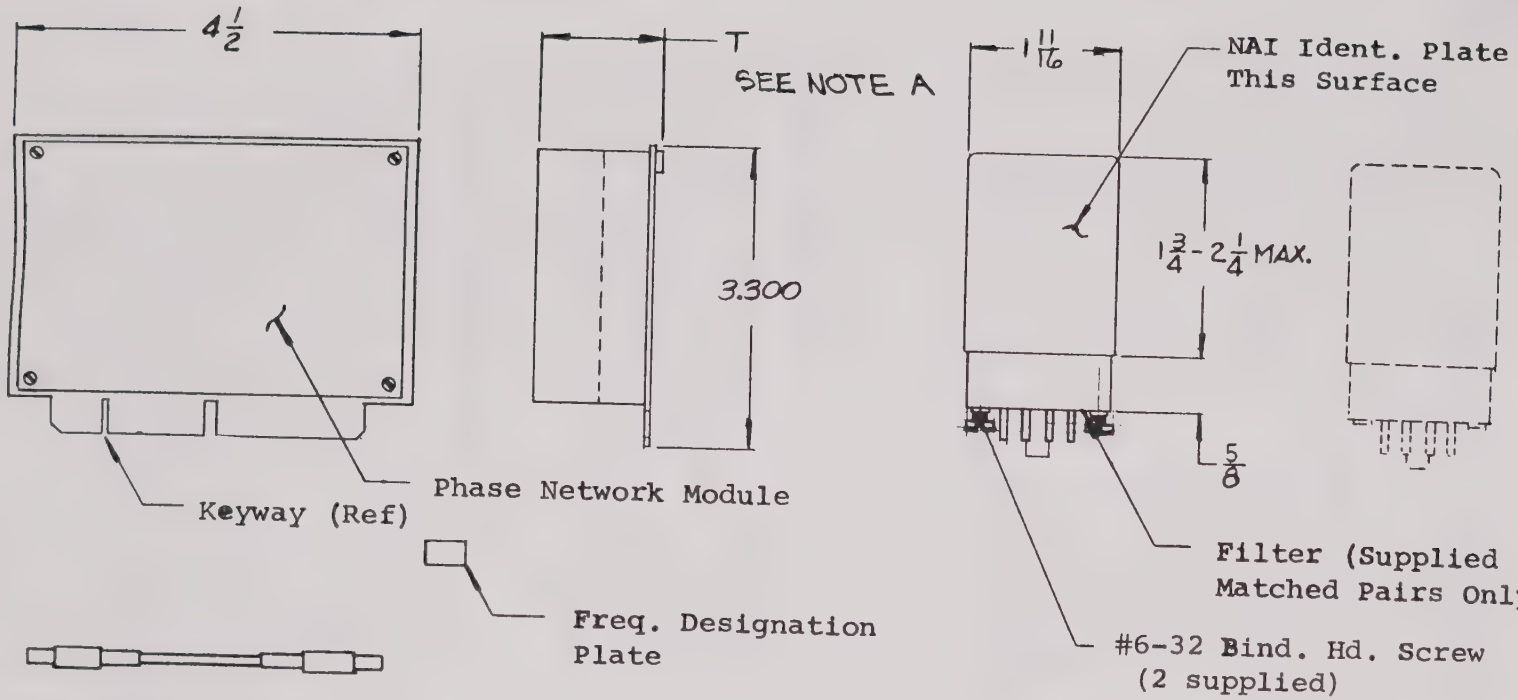

PLUG-IN MODULE KIT

KM 30

NOTE A

Freq. less than 60Hz T = 1-23/32
Freq. 60Hz to 400Hz T = 1-9/32
Freq. 400Hz to 10KHz T = 31/32
Freq. 10KHz to 20KHz T = 25/32

Figure 4.1

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INSTALLATION OF PHASE MODULES

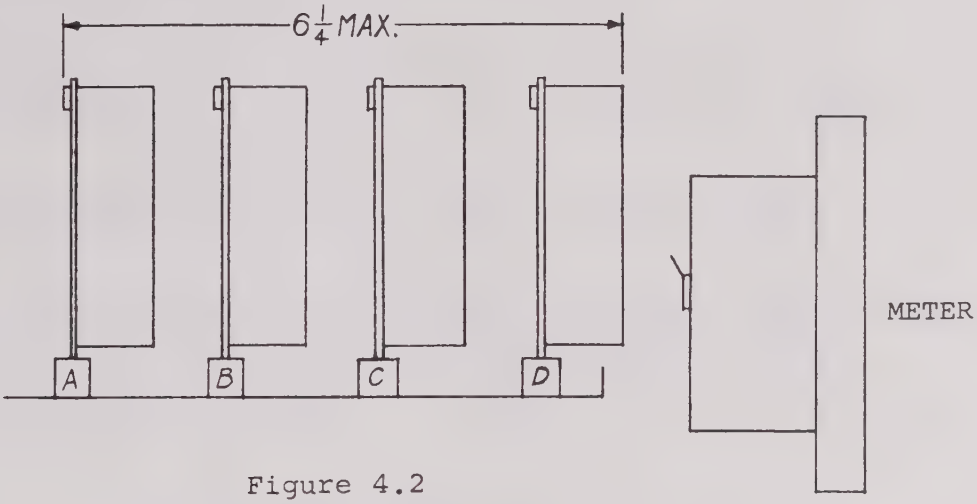

Figure 4.2

I. MODULE DIMENSIONS:

a. Frequencies below but not including 60Hz, thickness = 1-23/32
b. Frequencies of 60Hz up to but not including 400Hz, thickness = 1-9/32
c. Frequencies of 400Hz up to but not including 10KHz, thickness = 31/32
d. Frequencies of 10KHz to 20KHz, thickness = 25/32

II. FREQUENCY COMBINATIONS

Since connectors "B" and "C" (as shown in Figure 4.2) are movable, any combination of 4 frequencies can be installed providing the simple rules listed below are observed.

a. The module in the "D" position must be as indicated in Ic (31/32") or Id (25/32").

b. The total thickness of all 4 modules does not exceed 6-1/4". Note that this dimensional difficulty does not arise except where 2 or more frequencies are less than 60Hz.

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ISOLATION TRANSFORMERS (Optional) TM40, TM41, TM42
(See Figure 4.2 for Outline)

In order to allow the use of the Model 214 Phase Angle Voltmeter with isolated or floated inputs, the following special transformers were designed:

TM42, Reference Isolation Transformer (Used in Model 214B and 214C)

This transformer is designed for isolating the reference input signals and will operate over the entire phase sensitive frequency range of the Model 214. The Models 214B and 214C are equipped with a connector to receive this plug-in transformer.

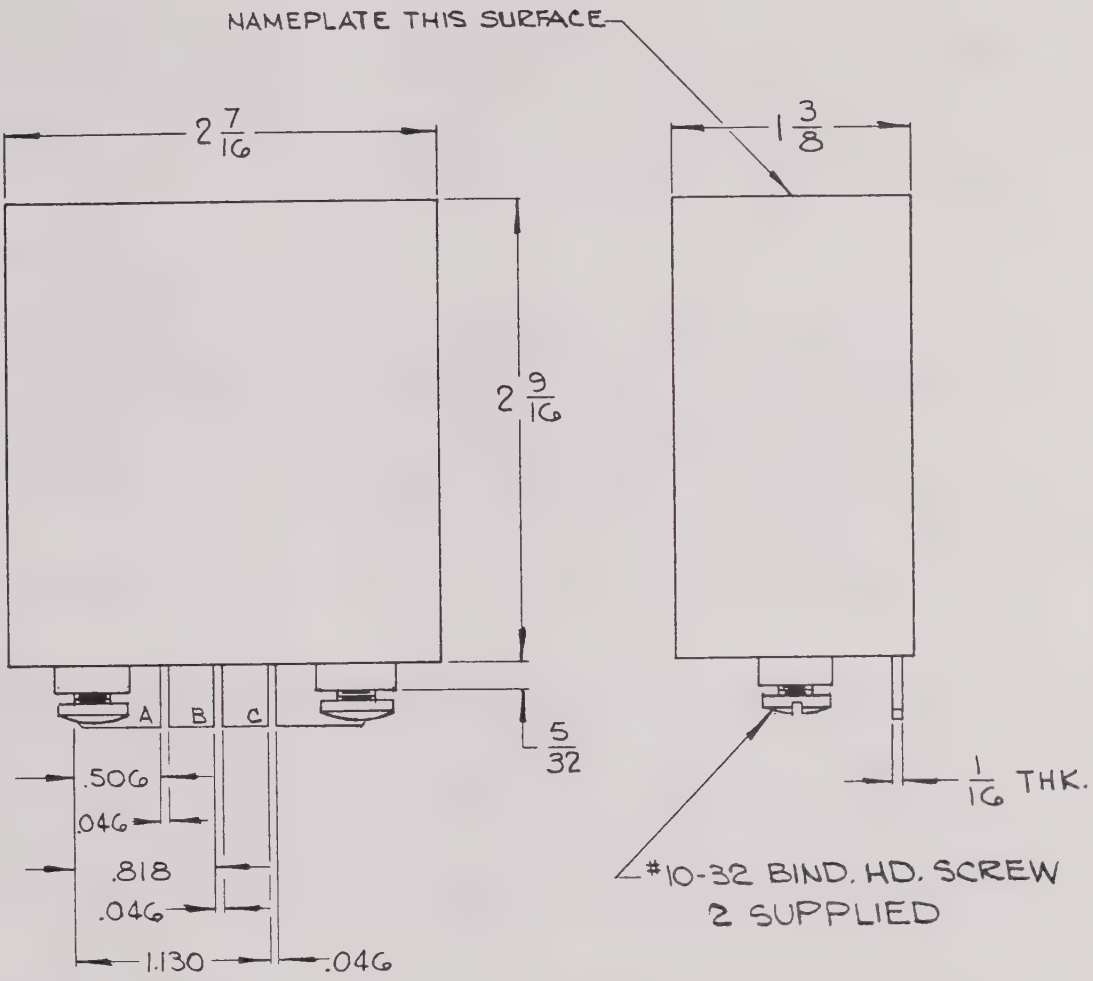
TM40, Signal Isolation Transformer, Low Frequency (Used in Model 214C)

This is a well-shielded, high quality transformer designed to operate within the frequency band of 30Hz to 2.5KHz. The maximum voltage rating of this transformer is limited to 0.75f (where f is the operating frequency) up to a maximum of 300V. The 214C is equipped with a connector to receive this plug-in transformer.

NOTE: For signals below 400Hz and above 10V, the alternate attenuator must be switched into the circuit (see Page 4.7,4.8).

TM41, Signal Isolation Transformer, High Frequency (Model 214C)

This transformer is similar in design to the TM41 transformer except that its frequency range is 2.5KHz to 20KHz and its voltage rating is 0.12f (where f is the frequency of operation) up to 300V maximum. It also plugs into a connector provided on the 214C chassis.



ISOLATION TRANSFORMER OUTLINE

This outline applies to all three Isolation Transformers. To prevent plugging a transformer into the wrong connector, each type is slotted as follows:

TM42 - Slot A
TM41 - Slot B
TM40 - Slot C

Figure 4.3

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The specific connections of the Signal Isolation Transformers are described in the following instructions for Model 214C.

Note TM40 and TM41 are protected from overload by fuse, F2, which is a 1/16A, 3AG Slo-Blo fuse, with a maximum resistance of 30Ω.

FREQUENCY SWITCH (S3) See Figure 4.4

The FREQUENCY Switch (S3) in the Model 214C has been constructed so as to provide maximum flexibility in the field. In the event that the frequency of any given channel is to be changed, the jumpers on TB1 and TB2 may be changed. The instrument as wired at the factory will have these jumpers arranged properly for the frequencies which are factory installed. If a frequency is to be changed or added, the change or addition of jumpers may be made by referring to the Frequency Change for 214C (Page 4.11).

The following is a discussion of the switch and jumper functions (See Figure 4.4).

The jumpers on TB2 are primarily for connecting the input signals to the proper transformer depending on the frequency of operation at any given position of the FREQUENCY Switch. In addition the alternate input attenuator may be removed or connected as required by the low frequency performance. This attenuator is required by the voltage limitation (f rating) of the low frequency transformer - i.e., .75f. In operation, the alternate 1000:1 attenuator is placed in front of the input transformers for voltage ranges 10V through 300V while the standard 1000:1 attenuator is by-passed.

The jumpers on TB1 perform three separate functions:

1. The first is to select the desired transformer output (TB2, Pins 7, 8, 13, 14, 15 and 16).

2. The second is to by-pass the standard 1000:1 attenuator in positions 10-13 of the RANGE Switch (S1) when the alternate input attenuator is switched into the circuit as in Case 4 or to maintain the

standard 1000:1 attenuator connection as in Cases 1, 2, and 3 (TB1, Pins 2, 3, 4, 5, 6 and 10, 11, 12, 17, 18).

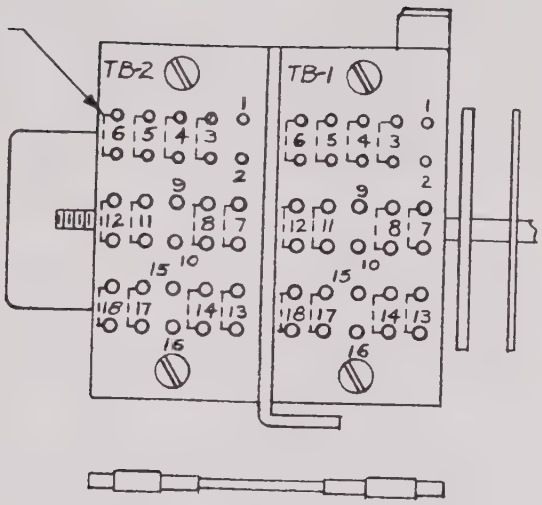
3. The third is to provide shielding between Pins 17 and 3 as in Cases 1, 2, and 3; or as in Case 4 a series connection through S3J and S3K for by-passing the standard 1000:1 attenuator as described in Step 2 above (TB1, Pins 10, 11, 12, 17, 18).

CAUTION: When the 214C is connected without the alternate attenuator (i.e., for frequency above 400Hz) care must be exercised that TOTAL measurements are not made which will exceed the f rating of the Signal Isolation Transformer (e.g., 60 cps line voltage). If it is desired to use the instrument in this manner, the alternate attenuator must be included as in Case 4 (Figure 4.9).

It must be recognized that this type of connection will cause a deterioration of the common-mode specification of the instrument in the 10V to 300V Ranges only. The degree of deterioration will depend on the frequency of operation.

When the alternate attenuator is added, its calibration should be checked. This may be done simply by injecting a 10V, 400Hz signal into the input terminals with the RANGE Switch in the 10V position. This adjustment must be made with the FUNCTION Selector in the TOTAL position and the FREQUENCY Switch set to a channel with a frequency of 400Hz or less. R103 (located on the RANGE Switch S1, see Figure 6.1) should then be readjusted, if necessary, to cause an exact full scale reading.

NOTE: TRANS/DIR Switch must be in the TRANS Position.



Jumper, NAI #202823
(Note: Remove with long-nose pliers)

FREQUENCY SWITCH (S3) -
TERMINAL BOARD CONFIGURATION

This is the physical arrangement of the terminal boards located on the Frequency Switch (S3). The jumper shown is universal and may be used to connect any pair of terminal points together. The number of jumpers will vary depending on the range and number of frequencies used. Note that two pins are provided with the same designating no. where necessary to facilitate interconnection. See text of Frequency Change Section for connection instructions. Note: Terminal No. 1 of TB-2 and Nos. 1 and 9 of TB-1 are spares.

CAUTION: AVOID APPLICATION OF SOLDER TO PINS ON TB1 AND TB2 SINCE THIS WILL PREVENT CONVENIENT CHANGING OF PIN BOARD LAYOUT.

Figure 4.4

NOTE: An adjustable stop is provided on the FREQUENCY Switch to prevent rotation to unused positions, in instruments which use less than four channels. It consists of a stop bar clamped to the switch shaft and a fixed stop pin located in the sub-panel. This stop may be readjusted in the following manner.

Remove the bottom cover of the instrument. Loosen the set screw which clamps the stop bar on the switch shaft. (This is clearly accessible from the underside between the front panel and the sub-panel). Rotate the switch to the most clockwise position to be used. Press the stop bar against the stop pin and re-tighten the set screw. The stop will now prevent the switch from rotating beyond the position selected.

FREQUENCY CHANGES - MODEL 214A AND 214B

The basic design of the Model 214 Phase Angle Voltmeter is such that 4 separate frequency channels may be used. In the event that the user wishes to change any of these frequencies after obtaining the instrument, the following procedure must be adhered to. A frequency of operation for an individual channel may be changed by replacing the phase module and the filters associated with that channel. This may be accomplished by simply removing the phase module, Model PM-10, and filters, Model FM-21, from their sockets and replacing them with the new modules.

The phase modules are factory calibrated and require no adjustment. It may be necessary to make some adjustment to the instrument due to variations in filter characteristics. The following adjustments can be made without any calibration test equipment. For chassis location of plug-in modules and adjusting controls, see Figure 4.10.

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Phase Adjustment

Connect any convenient signal of the module frequency to both the REF input and SIG input terminals. Set the FREQUENCY Switch to the proper position and adjust the Reference Level Control. Set the RANGE Switch to the most sensitive range before the OVERLOAD light turns on. This is to achieve maximum phase sensitivity. Switch the FUNCTION Switch to 90° and the Phase Dial to 0°. Adjust R23-A, B, C, or D located on the rear panel (corresponding to the channel affected) so that a null is achieved. The instrument is now phase aligned.

Amplitude Adjustment (This adjustment will rarely be necessary but should be checked and adjusted if maximum precision is desired.

Set the FREQUENCY Switch to the position in which the calibration is desired and the FUNCTION Switch to TOTAL. Connect a signal to the input terminals which will result in a near full scale deflection on any range. Note this reading. Set the FUNCTION Switch to FUND, and adjust R7-B, C, and D, located on the chassis, for the channel affected so that the deflection is identical to that in the TOTAL position. In the event the replacement takes place in Channel A, it will be necessary to readjust R11 (Fundamental Gain Adjust). If this latter adjustment is made, it will be necessary to recheck the adjustment of R-7B, C, and D (individual filter gain adjustments).

FREQUENCY CHANGE - MODEL 214C

In those instruments (Model 214C) containing signal isolation it should be noted that there are one or two transformers, each for specific frequency bands. The frequency to which the user wishes to convert must be associated with the isolation transformer

which covers that frequency. The frequency calibration procedure applies in addition to the information in the following paragraphs. The low frequency transformer (T1) is preferred for frequencies from 30Hz to 2.5KHz. The higher frequency transformer (T2) is for use between 2.5KHz and 20KHz. See "Isolation Transformers" in the preceding portion of this section for details regarding voltage limitations.

In the event that a channel must be converted for use with a frequency which is in a different band (using a transformer), the jumpers at the top of the FREQUENCY Switch, S3 (See Figure 4.4) must be changed. Specific instructions for changing these jumpers are contained in the following paragraphs with typical case examples to aid the user. Note the additional blank work sheets which are provided to permit the user to keep a record of other hookups (Figure 4.5).

CASE 1: (See Figure 4.6 - All four channels are between 400Hz and 2.5KHz

For frequencies between 400Hz and 2.5KHz, jumpers are connected such that T1 only (TM40) is in the circuit. For frequencies above 400Hz, the alternate or low frequency 1000:1 attenuator is by-passed (TB2-14 to 3). Where this attenuator is not used, the standard 1000:1 attenuator must be connected in position 10 through 13 of the RANGE Switch. This is accomplished in this case by connecting all the terminals at S3K together. Jumpers S3J are to ground unused terminals (TB1-10, 12, 11, 18).

Connect:

TB1

16-14	3-4	10-12
14-13	4-5	12-11
13-7	5-6	11-18
7-8		

TB2

14-3	3-4	15-17
13-14	4-5	17-18
7-13	5-6	18-12
8-7		12-11

See CAUTION Note, Page 4.8.

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CASE 2: (See Figure 4.7) - All four channels are between 2.5KHz and 20KHz.

For frequencies between 2.5KHz and 20KHz, jumpers are connected such that T2 (TM41) only is in the circuit. The low frequency 1000:1 attenuator is again by-passed and the jumper arrangement at the standard 1000:1 attenuator (TB1-3, 4, 5, 6) are the same as Case 1. TB1-10, 12, 11, 18 are jumpered to ground unused terminals.

Connect:

TB1

14-13	3-4	10-12
13-7	4-5	12-11
7-8	5-6	11-18
8-15		

TB2

14-13	17-18
13-7	18-12
7-8	12-11
8-9	11-16

See Caution Note on Page 4.8.

CASE 3: (See Figure 4.8) - 2 channels between 400Hz and 2.5KHz
2 channels between 2.5KHz and 20KHz

For frequencies between 400Hz and 20KHz where jumpers are connected to use both T1 (TM40) and T2 (TM41). The low frequency 1000:1 attenuator is by-passed and the jumper arrangement at the standard 1000:1 attenuator (TB1-3, 4, 5, 6) are the same as Cases 1 and 2. TB1-10, 12, 11, 18 are jumpered to ground unused terminals.

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Connect:

	TB1	
16-14	3-4	10-12
14-13	4-5	12-11
7-8	5-6	11-18
8-15		

	TB2	
14-3	15-17	3-4
14-13	17-18	
7-8	12-11	
8-9	11-16	

See Caution note on Page 4.8.

CASE 4: (See Figure 4.9) - 1 channel below 400Hz (Channel A)
1 channel between 400Hz and 2.5KHz (Channel B)
2 channels between 2.5KHz and 20KHz (Channels C and D)

For a combination where a frequency below 400Hz is to be included, both transformers are connected much in the same manner as Case 3. This requires that the 1000:1 low frequency attenuator be used to limit the voltage, due to the f rating of the transformer (see "Transformer", Page 4.5). Particular attention must be paid to the jumper connections at S3J and S3K. In this case, the standard 1000:1 attenuator is switched out of the circuit in positions 10 to 13 of the RANGE Switch (S1). At the same time, the low frequency 1000:1 attenuator is switched into the circuit. This will provide the same overall sensitivity of the instrument, while limiting the low frequency voltage applied to the transformer. Where frequencies below 60Hz are to be included, the number of phase modules may be limited (see Page 4.4, Figure 4.2).

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Connect:

	TB1	
16-14	2-3	17-18
14-13	4-5	10-12
7-8	5-6	12-11
8-15		

	TB2	
14-10		17-15
13-4		17-18
7-8		12-11
8-9		11-16
2-3		

See Caution note on Page 4.8.

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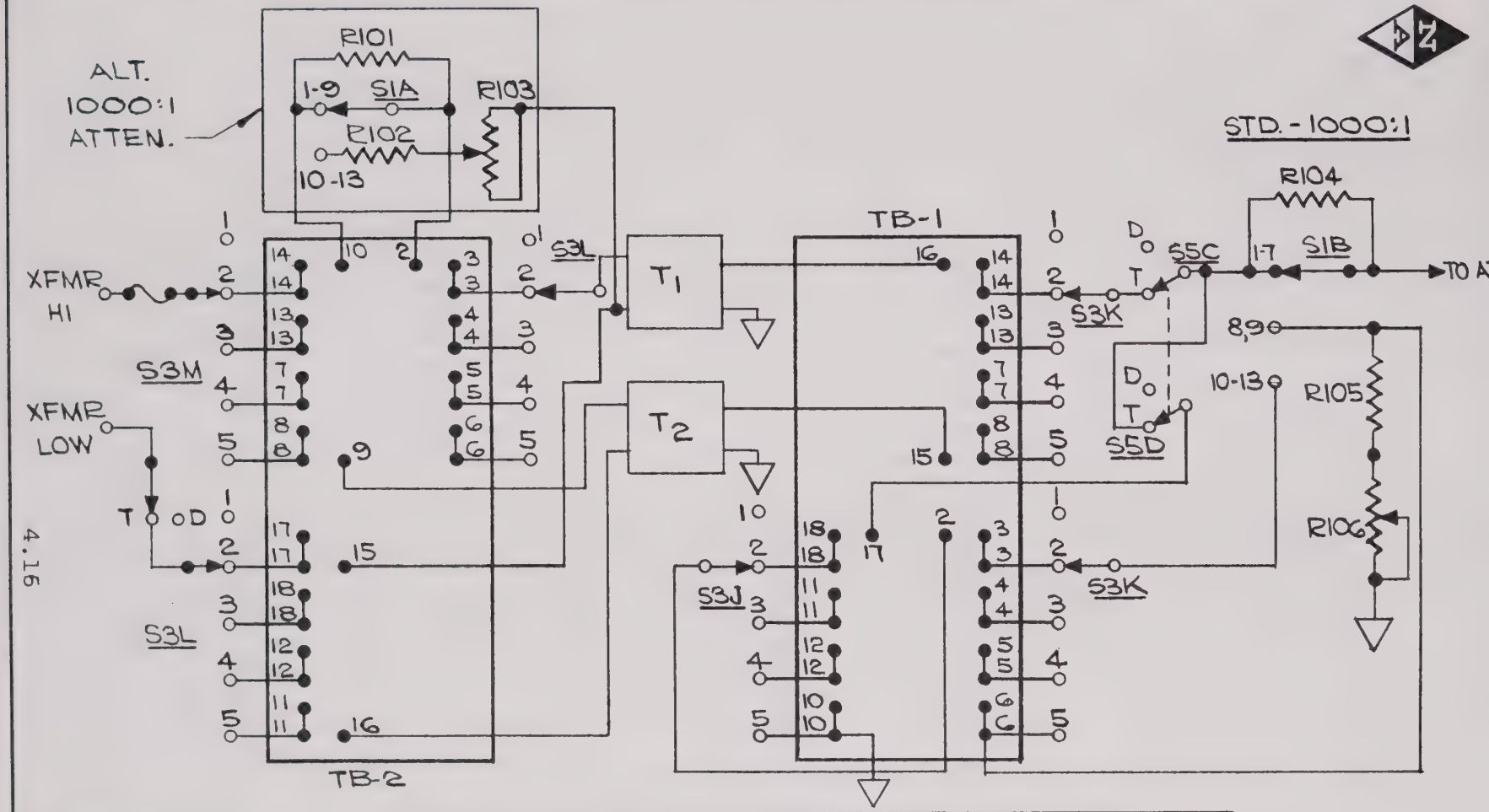

S3 POSITIONS
(FREQUENCY SW.)

1 - OFF
2 - CHANNEL - A
3 - CHANNEL - B
4 - CHANNEL - C
5 - CHANNEL - D

ENTER FREQUENCY	TRANSFORMER T1 TM 41 T2 TM 42		ATTENUATOR (CHECK IF USED)	
	T1	T2	ALT.	STD.

WORK SHEET - 214C JUMPER DIAGRAM
DRAWN BY_____ DATE_____SERIAL #_____

Figure 4.5

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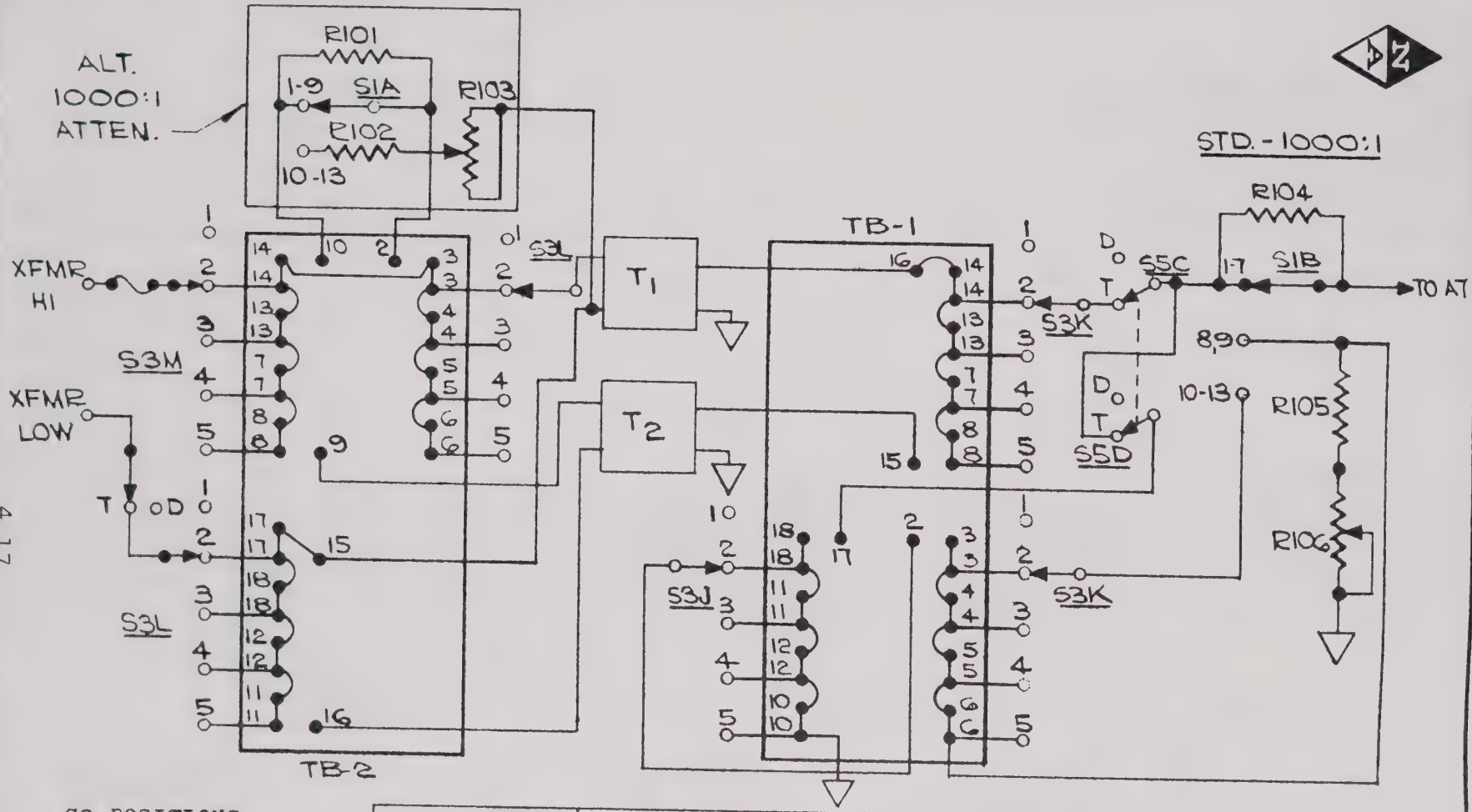


S3 POSITIONS
(FREQUENCY SW.)

1 - OFF
2 - CHANNEL - A
3 - CHANNEL - B
4 - CHANNEL - C
5 - CHANNEL - D

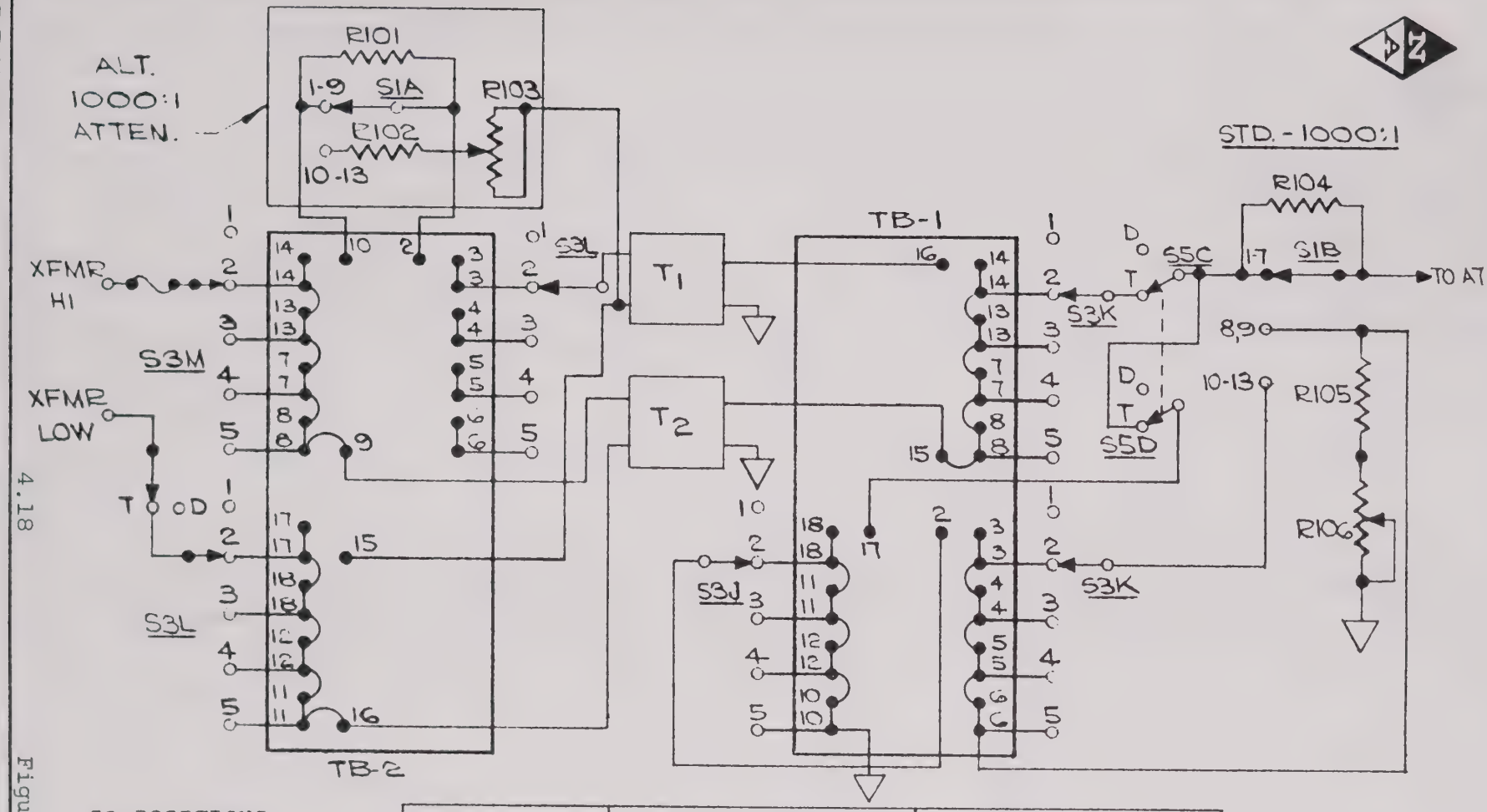
CASE 1
400Hz to 2.5KHz

ENTER FREQUENCY	TRANSFORMER T1 TM 41 T2 TM 42		ATTENUATOR (CHECK IF USED)	
	T1	T2	ALT.	STD.
400Hz	X			X
800Hz	X			X
1.2KHz	X			X
2.4KHz	X			X

WORK SHEET - 214C JUMPER DIAGRAM
DRAWN BY _____ DATE _____ SERIAL # _____

4.17

Figure 4.6



S3 POSITIONS
(FREQUENCY SW.)

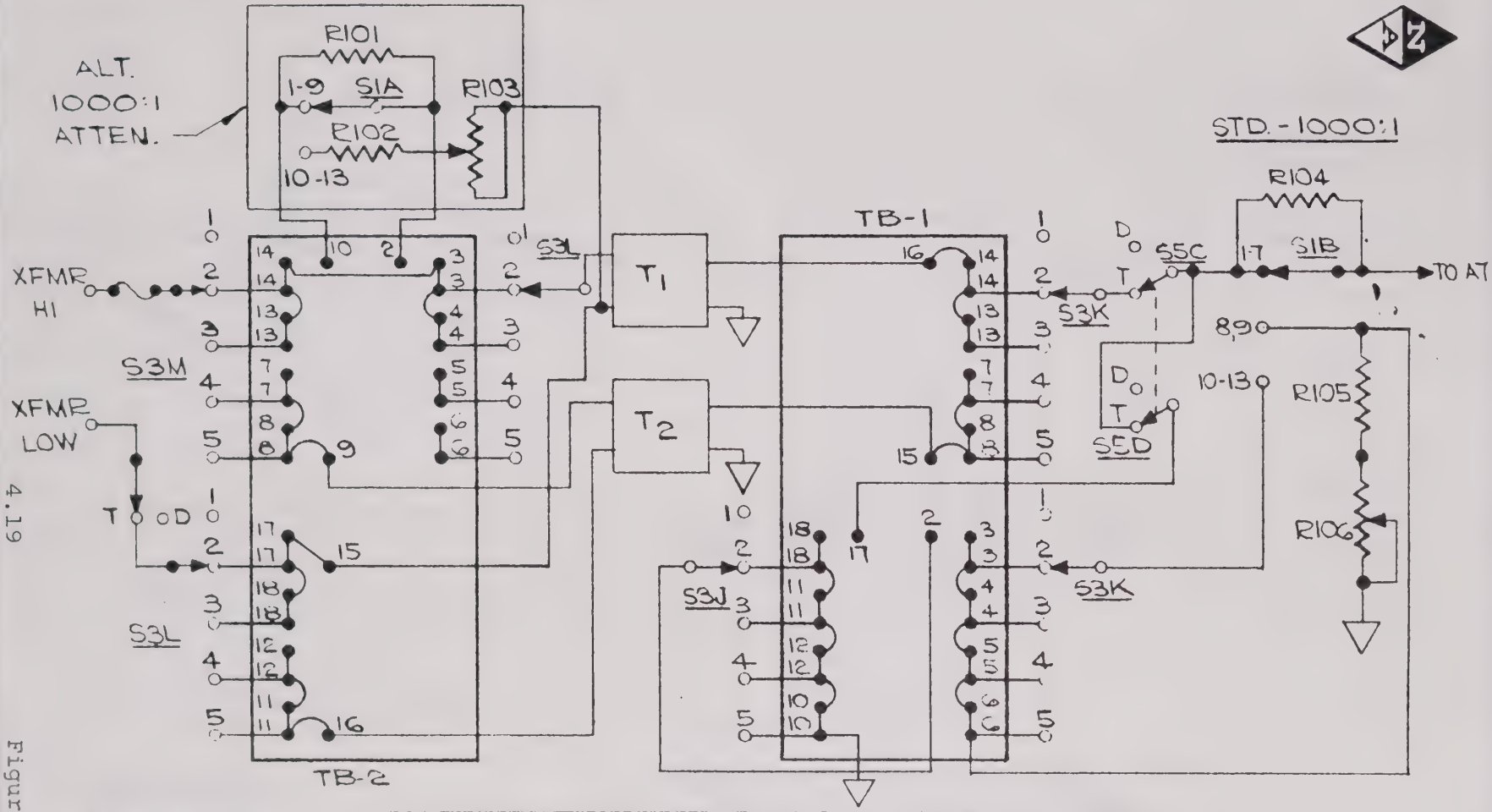
1 - OPP
2 - CHANNEL - A
3 - CHANNEL - B
4 - CHANNEL - C
5 - CHANNEL - D

CASE 2
2.5KHz to 20KHz

ENTER FREQUENCY	TRANSFORMER T1 TM 41 T2 TM 42		ATTENUATOR (CHECK IF USED)	
	T1	T2	ALT.	STD.
3.2KHz		X		X
4.8KHz		X		X
10KHz		X		X
20KHz		X		X

WORK SHEET - 214C JUMPER DIAGRAM
DRAWN BY_____ DATE_____ SERIAL #_____

Figure 4.7



S3 POSITIONS
(FREQUENCY SW.)

1 - OFF
2 - CHANNEL - A
3 - CHANNEL - B
4 - CHANNEL - C
5 - CHANNEL - D

ENTER FREQUENCY	TRANSFORMER T1 TM 41 T2 TM 42		ATTENUATOR (CHECK IF USED)	
	T1	T2	ALT.	STD.
400Hz	X			X
1KHz	X			X
10KHz		X		X
20KHz		X		X

CASE 3
400Hz to 2.5KHz, 2.5KHz to 20KHz

WORK SHEET - 214C JUMPER DIAGRAM
DRAWN BY_____ DATE_____ SERIAL #_____

Figure 4.8

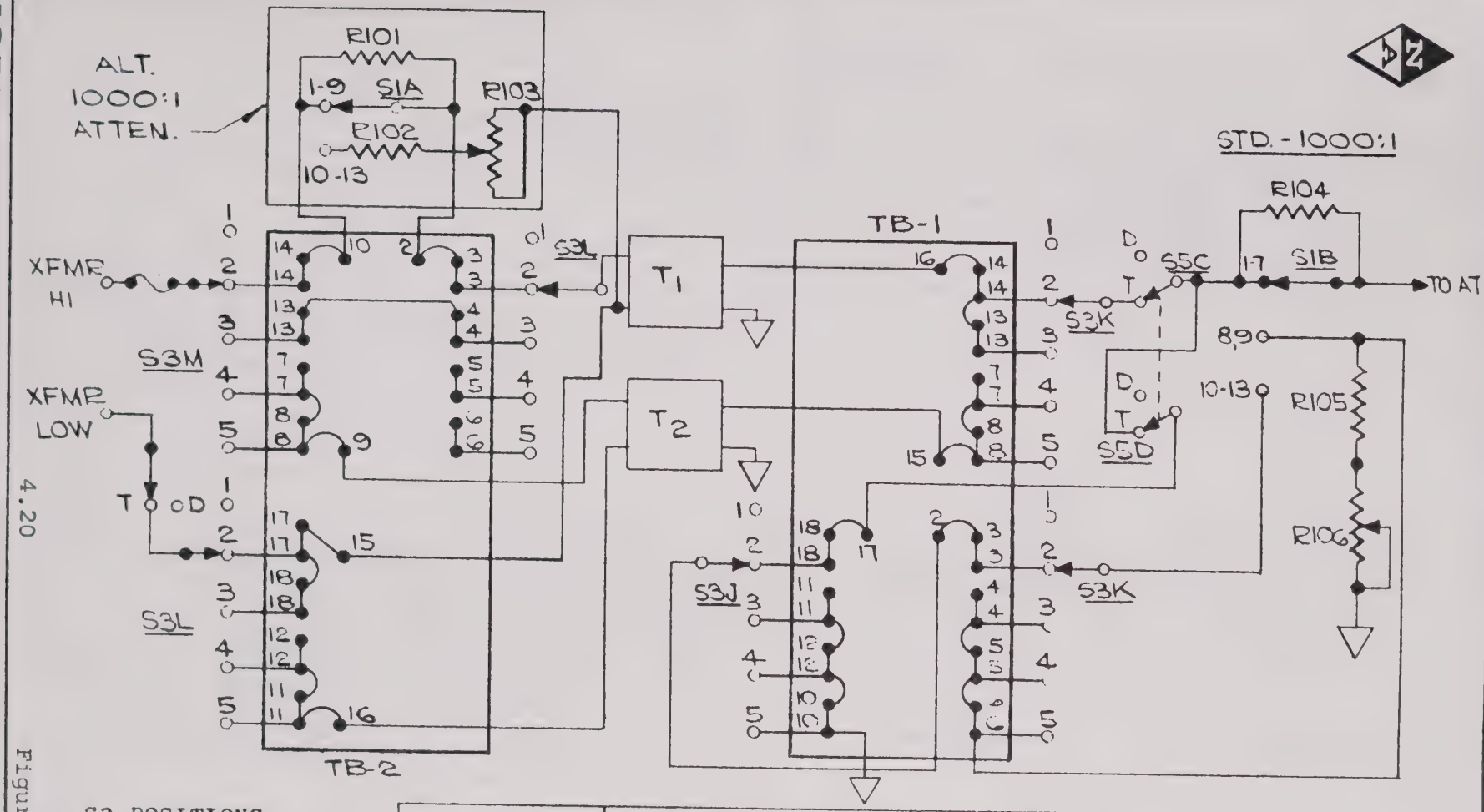


Figure 4.9

S3 POSITIONS
(FREQUENCY SW.)

1 - OFF
2 - CHANNEL - A
3 - CHANNEL - B
4 - CHANNEL - C
5 - CHANNEL - D

CASE 4 - Under 400Hz,
400Hz to 2.5KHz,
2.5KHz to 20KHz

ENTER FREQUENCY	TRANSFORMER T1 TM 41 T2 TM 42		ATTENUATOR (CHECK IF USED)	
	T1	T2	ALT.	STD.
60Hz	X		X	
400Hz	X			X
3.2KHz		X		X
10KHz		X		X

WORK SHEET - 214C JUMPER DIAGRAM
DRAWN BY_____ DATE_____ SERIAL #_____

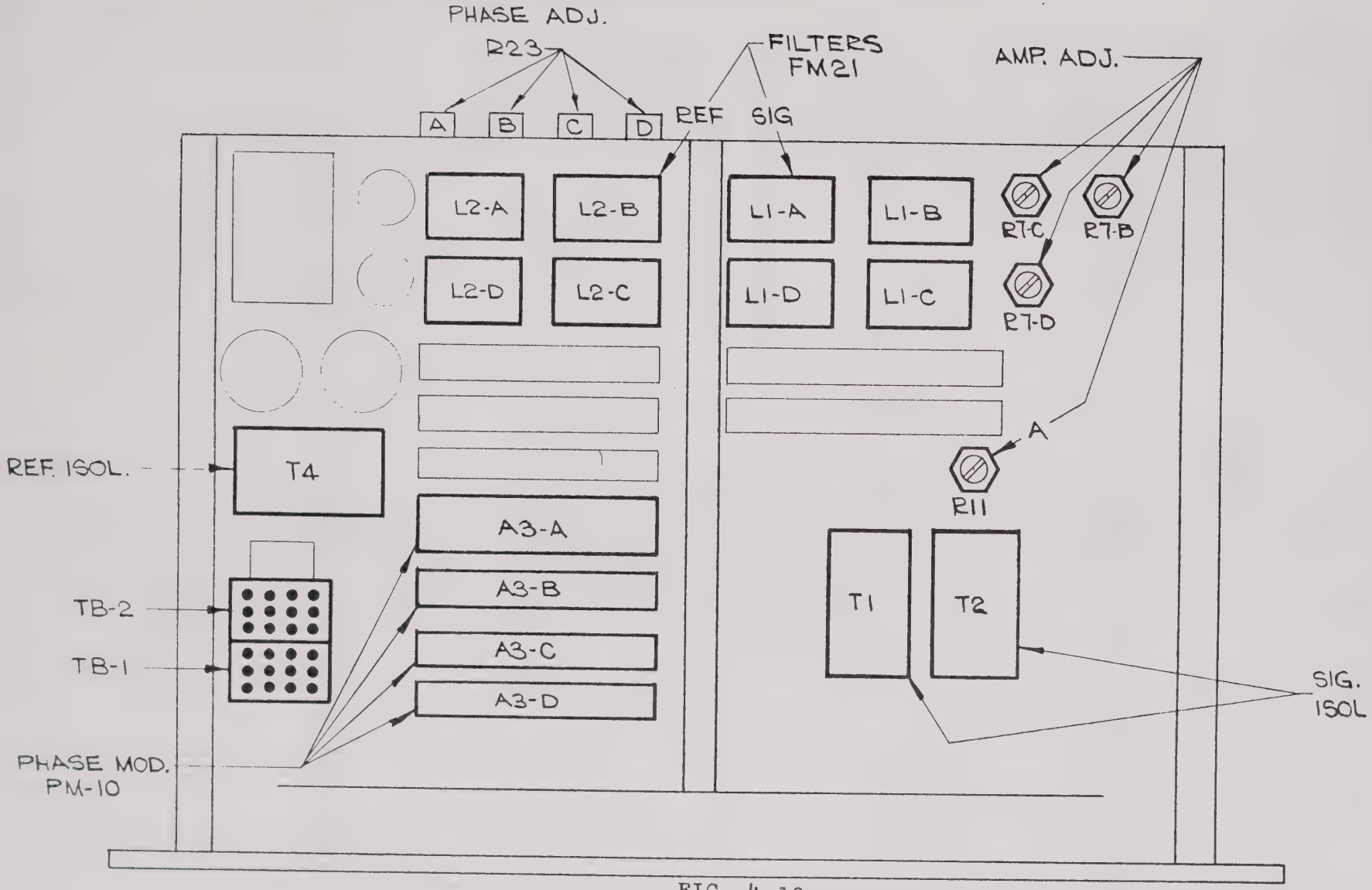


FIG. 4.10
LOCATION DIAGRAM
PLUG IN MODULES AND ASSOCIATED CONTROLS.
214C TOP

SECTION V

MAINTENANCE

The following section contains instructions for the general maintenance of the Phase Angle Voltmeter. All alignment procedures are described in Section VI.

COVER REMOVAL

In order to service or change frequencies, it is necessary to remove the top cover of the instrument via the removal of 5 screws. For additional trouble shooting and maintenance, it may become necessary to remove the bottom cover of the instrument which may easily be accomplished by removing 5 screws.

REPLACEMENT OF MODULES

With the top cover removed, remove the module hold-down bracket to replace any of the modules in their sockets. Care must be exercised to insure that a module is replaced with the same type. Filters may be replaced or changed by removing the screws from the underside and unplugging the filter to be replaced. For repair or replacement, the exact replacement filter pairs must be used. For frequency change, the filter for the frequency of operation should be plugged into the proper socket designated by Channels A, B, C, or D. The hold-down screws should then be replaced.

Where a frequency change is to take place, the proper phase module must also be plugged into the proper J3 socket for the given channel. It should be noted that where a 30Hz channel is used, the number of channels which can be activated are limited by the physical dimensions of the 30Hz phase module. A 30Hz phase the use of additional Channels C and D (B socket will be inaccessible). (See Section IV.)

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POWER SUPPLY

The Power Supply, being the only module containing components with appreciable operating stress, may require occasional maintenance. The components within the supply are generally of the most dependable type available. However, should it become necessary to replace any of these components, only identical components should be used. The module may be easily opened by removing it from its socket and removing the 4 screws holding the cover in place. All precautions consistent with good practice should be exercised in the replacement of any component.

REPLACEMENT OF CHASSIS COMPONENTS

There are a limited number of components which are mounted directly to the chassis, all of which are easily accessible. In the event that any of these must be replaced, normal precautions consistent with good manufacturer practice should be followed.

There are a number of components which are mounted to switch assemblies. In the event there is a failure in any of these components, it is recommended that the switch be replaced as a complete assembly where possible.

REPLACEMENT OF FUSES

There are two fuses used in the Model 214 Phase Angle Voltmeter. The first fuse is a power fuse mounted on the rear panel of the unit and may easily be replaced by removing the fuseholder cap. This fuse will normally be a .5 amp fuse, Type 3AG, for those instruments which operate with 115V power. For those instruments which operate with 230V power, this fuse should be a .25 amp, Type 3AG.

The second fuse is used only in Model 214C instruments which contain the signal isolation transformer(s). This is a 1/16A, 3AG, Slo-Blo fuse which is located on the front panel and may be replaced by

removing the cap from the fuseholder. A spare is located adjacent to this fuse in a similar fuseholder. Replacements for this fuse should not have a resistance greater than 30Ω as this will create errors in excess of the specified limits. A type 3AG is recommended.

ISOLATION AMPLIFIER REPLACEMENT

All units, Serial No. 1026 and above, have isolation amplifiers in both Signal and Reference Channels (A7 and A8, respectively) which are directly replaceable by spares supplied. However, instruments Serial No. 1001 through 1025 had an early version of these isolation amplifiers. To replace same in latter instruments, some modification is needed. The up-to-date amplifier may be recognized by the fact that it has five (5) terminals whereas the earlier version had four (4). In addition, a letter suffix (A, B, etc) is added to the Part No. on the nameplate.

To change the instrument, perform the following:

Signal Isolation Amplifier Module (A7):

a. Add a wire from the junction of C104, C105, and R107 located on the RANGE Switch (S1) to Pin 5 of the new isolation module (see Figure 3.2).

b. Frequency response may be effected (in Total Mode). This should be checked and C12 and R35 added across R2 if required. See Page 6.15, "Frequency Response Trim."

Reference Isolation Amplifier Module (A8):

Add wire from the junction of C3 and R103 to Pin 5 of the new Reference Isolation Amplifier Module.

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REPLACEMENT PARTS LIST

Designation	Description	NAI Part No.	Manufacturer
A1	Preamplifier Overload/Demodulator	782251	
A2	Signal Amplifier	782245	
A3	*Phase Module		
A4	Reference Drive Amplifier	782247	
A5	Reference Amplifier	782246	
A6	Power Supply	782332	
A7	Isolation Amplifier	782270-1	
A8	Isolation Amplifier	782270-3	
A9	Isolation Amplifier	782270-4	
	(after S/N 1265)	**782270-2**	
L1-A,B,C,D L2-A,B,C,D	Filter, Low Pass (See Table II, Page 3.14)		
C1,C2	Capacitor, 3 x 40, 150V	803317	
C3	Capacitor, Fixed, 100uf, 25V	803059	
C4	Capacitor, Fixed, 50uf, 25V	803199	
C5,C9	Capacitor, Fixed, .047uf, 400V	802395	
C6	Capacitor, Variable, 3 x 12uuf	801512	
C7	Capacitor, Fixed, 33uuf **(214B+C)**	803610	
	Capacitor, Fixed, 22uuf, (214A only)	**802336**	
C8	Capacitor, Fixed, 2700uf, 300V	803609	
C12	Capacitor, Fixed, 50uuf	801685	

* Order by PM10-Freq. (See Section IV.)

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Consistent with North Atlantic Industries' policy of continuously up-grading components and improving circuits, we reserve the right to substitute components which are functionally interchangeable for any of the parts shown above.

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REPLACEMENT PARTS LIST

DESIGNATION	DESCRIPTION	NAI PART NO.	Manufacturer
R1,R7B,C,D	Potentiometer, 10K	800007	
R2,R15-R22	Resistor, Fixed, D.C., 10K, 1/2W ±1%	801481	
R4,R5,R6	Resistor, Fixed,D.C., 7.5K, 1/2W, ±1%	803326	
R8	Potentiometer, 10K (Special)	202643	
R11,R12	Potentiometer, 50Ω	800010	
R13	Resistor, Fixed, M.F., 10Meg. 1/2W, ±3%	803633	
R14	Resistor, Fixed, D.C., 150K, 1/4W,±1% (110K, 1/4W, 1%, 214A only)	803635 802195	
R23A,B,C,D,	Potentiometer, 1.5K	803440	
R24,R26,R28 R30	Resistor, Fixed, Comp., 750Ω, 1/2W ±5%	800911	
R25,R27,R29 R31	Resistor, Fixed, Comp., 1.8K, 1/2W ±5%	800858	
R32	Resistor, Fixed, Comp., 12K, 1/4W	803228	
R33	Resistor, Fixed, Comp., 240Ω, 1/4W	802231	
R34	Resistor, Fixed, WW, 25Ω, 3W,±5%, (This resistor is used only with power transformer T7, NAI#202581, and is omitted when power transformer NAI #202819 is used).	800075	
R35	Resistor, Fixed, Comp., 10K, 1/4W	801413	
XF1	Fuse Holder	800117	
F1	Fuse, 1/2 amp.	802900	Littlefuse 312.500 or equa

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REV. 3-17-71

REPLACEMENT PARTS LIST

Designation	Description	NAI Part No.	Manufacturer
I1	Lamp Cartridge, Overload	803319	
I2,I5	Lamp	802767	Chicago Lamp Works, #1768
M1	Meter	202556	
I3,I4	Light, Meter	803611	GE #51
S4	Switch, Reference HI-LO Assembly	803318	
T5,T6	Reference Drive Transformer and Reference Transformer	202348	
T7	Power Transformer	202581	
	Line Cord	500502	
	Knob, Large Round	201724	
	Knob, Large Pointer	201837	
	Knob, Large Pointer Modified	202159	
	Knob, Small Round	201720	
	Binding Post, Black	800120	
	Binding Post, Red	800119	
	Binding Post	800546	

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REPLACEMENT PARTS LIST

Designation	Description	NAI Part No.	Manufacturer
XI2,XI5	Socket	802768	Dialco #16-08
	Speed Clip (I1 mounting)	802952	
XI1	Connector	802951	
	Adapter, 1/4 to 1/8 shaft (used with 201720 knob)	202144	
S1	Range Switch Assembly	500557	
C101	Capacitor, Variable, 3-12uf	801512	
C102	Capacitor, Fixed, 22uuf	802572	
C103	Capacitor, Fixed, .027uf	802571	
C104	Capacitor, Fixed, 25uf, 25V	803342	
C105	Capacitor, Fixed, **Select at Test**		
R104	Resistor, Fixed, M.F., 10M, ±3%	803633	
R105	Resistor, Fixed, M.F., 9.5K, ±1%	803634	
R106	Resistor, Variable, 1K	803341	
R107	Resistor, Fixed, 100K, 1/2W, ±10%	800086	
R108	Resistor, Fixed, M.F., 6.84K, 1/8W, ±1/4%	801474	
R109	Resistor, Fixed, M.F., 2.16K, 1/8W, ±1/4%	801475	
R110	Resistor, Fixed, M.F., 684Ω, 1/8W, 1/4%	801476	
R111	Resistor, Fixed, M.F., 216Ω, 1/8W, ±1/4%	801477	

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REPLACEMENT PARTS LIST

DESIGNATION	DESCRIPTION	NAI PART NO.	MANUFACTURER
R112	Resistor, Fixed, M.F., 68.4Ω, 1/8W, ±1/4%	801478	
R113	Resistor, Fixed, M.F., 21.6Ω, 1/8W, ±1/4%	803431	
R114	Resistor, Fixed, M.F., 10Ω, 1/8W, ±1/4%	803000	
R115	Resistor, Fixed, 23.5K, 1/2W, ±1%	803483	
R116	Potentiometer, 10K	802589	
R117	Resistor, Fixed, M.F., 3K, 1/2W, ±1%	803482	
R118	Resistor, Fixed, Comp., 470Ω, 1/4W, ±10%	803223	
S2	Function Switch Assembly	500558	
R201,R202, R203,R204	Resistor, Fixed, M.F., 2.4K, 1/4W, ±5%	806079	
R205,R208	Resistor, Fixed, M.F., 21K, 1/4W, ±1/4%	803001	
R206,R209	Resistor, Fixed, M.F., 63Ω, 1/4W, ±1/4%	803002	
R207	Resistor, Fixed, M.F., 665Ω, 1/4W, ±1%	803478	
R210,R212	Resistor, Fixed, M.F., 7.38K, 1/4W, ±1%	803479	
R211	Resistor, Fixed, M.F., 8.25K, 1/4W, ±1%	803480	
CR201-to CR204	Diode, 1N3069	802924	

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REPLACEMENT PARTS LIST

(2) R2 was 430Ω, 2W, and R6 was 910Ω, 2W, on all units below Serial No. 1040

Designation	Description	NAI Part No.	Manufacturer
S3	Frequency Switch Assembly	500618	
R301	Potentiometer, 2K	202540	
R302	**Resistor, Fixed, Comp., 27Ω, 1/2W, ±5%** **Resistor, Fixed, Comp., 20Ω, 1/2W, ±5%** **(214A only)**	800612 804266	
S7	Switch, Power (mounted on and actuated by S3)	803706	
	Power Supply Assembly	782332	
C1	Capacitor, Fixed, .022uf, 400V	803177	
R1	Resistor, Fixed, Comp., 1.5K, 1W, ±10%	803208	
R2 (2)	Resistor, Fixed, Comp., 360Ω, 5W, ±5%	803792	
R3	Resistor, Fixed, Comp., 2.2K, 1/2W, ±10%	800829	
R4	Resistor, Fixed, Comp., 1.8K, 1/2W, ±10%	800499	
R5	Resistor, Fixed, Comp., 33Ω, 1/2W, ±10%	800413	
R6 (2)	Resistor, Fixed, Comp., 900Ω, 3W, ±5%	801635	
R7	Resistor, Fixed, Comp., 100Ω, 1/2W, ±10%	800631	
CR1-CR4	Diode, 1N645	800323	
CR5, CR6	Diode, 1N972B	803205	
CR7	Diode, 1D30B	801203	
Q1, Q2	Transistor, 2N697	802107	

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REPLACEMENT PARTS LIST

DESIGNATION	DESCRIPTION	NAI PART NO.	MANUFACTURER
	VM-214B		
T4	Reference Isolation Transformer (TM42)	782333	
	VM-214C		
T1	Signal Isolation Transformer TM40 (for frequencies 30Hz to 2.5KHz)	782395	
T2	Signal Isolation Transformer TM41 (for frequencies 2.5KHz to 20KHz)	782396	
T4	Reference Isolation Transformer (TM42) (After S/N 1265)	782333 (782333-1)	
XF2	Fuse holder	803485	
F2	Fuse, 1/16 amp.	804054	BUSS type MDL only
S1	Range Switch Assembly (Those components listed under 500557 apply along with the following additions)	500621	
R101	Resistor, Fixed, M.F., 100K, 1W, ±2%	807380	
R102	Resistor, Fixed, M.F., 90Ω, ±1%	803366	
R103	Resistor, Variable, 100Ω	803367	
S5	Switch Assembly	500588	
C20	Capacitor, Fixed, Mica, 1pf, 500V	802619	
S3	Switch, Frequency Assembly	500552	
	Jumper (See Section IV for details)	202823	

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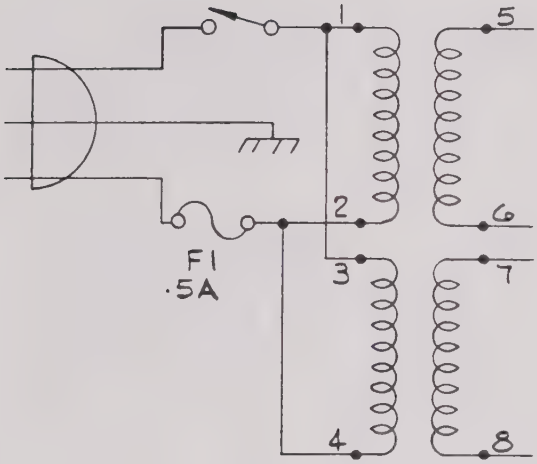
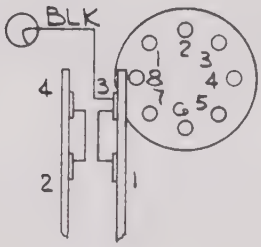
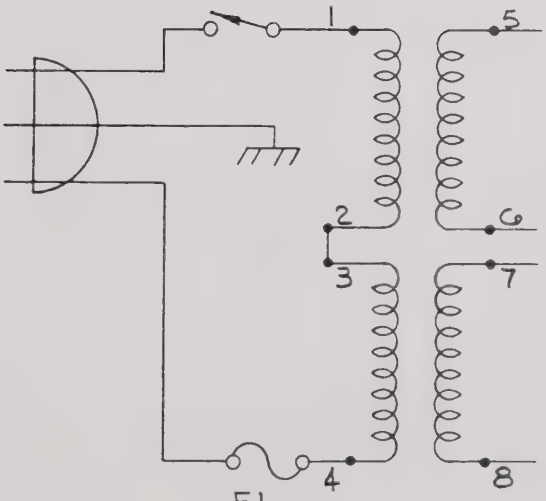
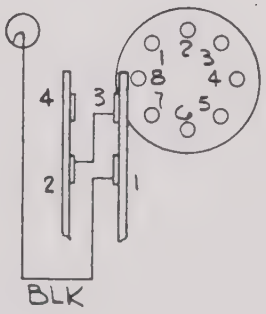
INPUT CONVERSION
FOR
POWER TRANSFORMER
202581





115V CONNECTION





230V CONNECTION

To convert from 115V connection to 230V connection:

1. Remove jumpers 1 to 3 and 2 to 4.
2. Move Black wire from 3 to 1.
3. Add jumper 2 to 3.

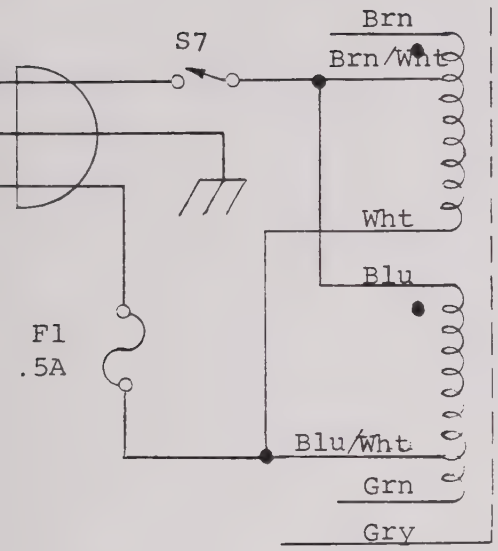
Figure 5.1

Power Transformer (T7) NAI #202581 has been replaced by NAI # 202819. This transformer incorporates additional flexibility which allows the use of a greater variety of power input voltages. It may be used for voltages of 115V, 125V, 230V, or 250V (±10%). See Figures 5.2A, B, C, and D.

This new transformer (202819) is different physically from transformer 202581. It can be used to replace the # 202581 transformer by the use of commercially available hardware. It should be mounted in an elevated position above the chassis and the leads may then be run through the existing hole in the chassis. In order to elevate the transformer, washers may be used to provide the required spacing.

NOTE: The schematic diagram of the power transformer primary as shown in Figure 5.2 will affect schematic Figure 3.3

INPUT CONVERSION
FOR
POWER TRANSFORMER
202819



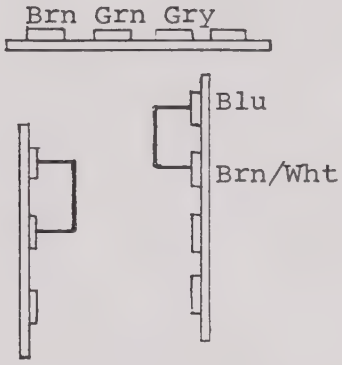
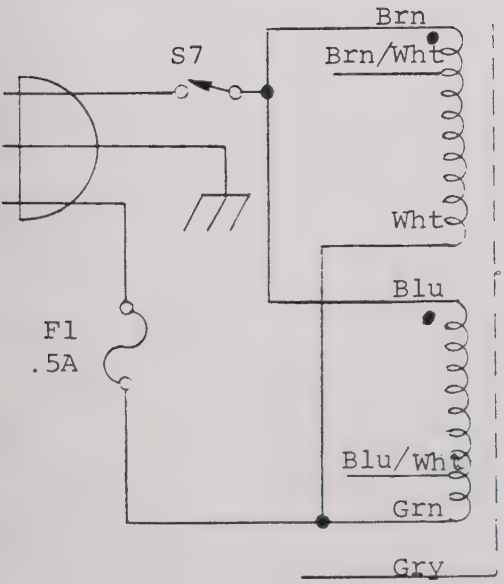


FIGURE 5.2A
115V Connection
Jumper Blu/Wht to Wht
Brn/Wht to Blu



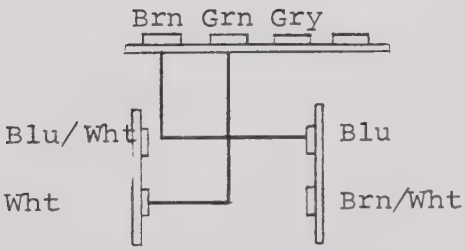
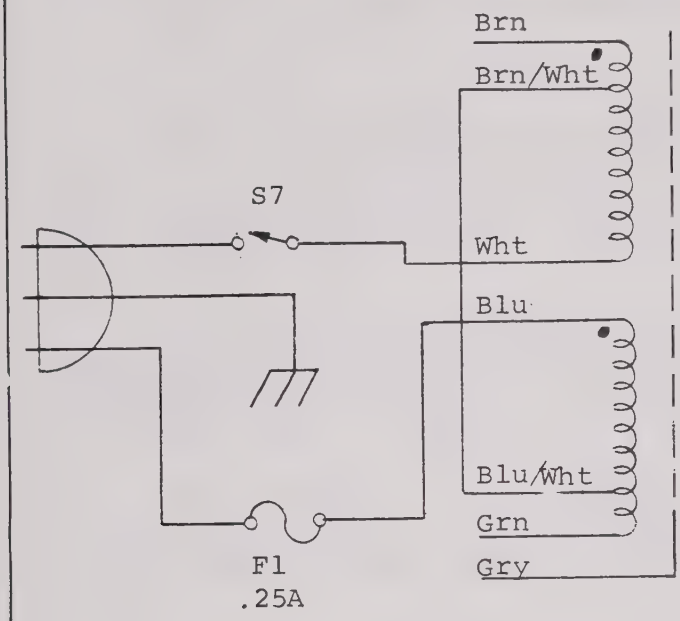


FIGURE 5.2B
125V Connection
Jumper Grn to Wht
Brn to Blu

1/16/67

INPUT CONVERSION
FOR
POWER TRANSFORMER
202819



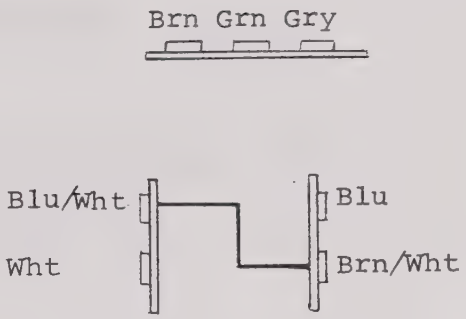
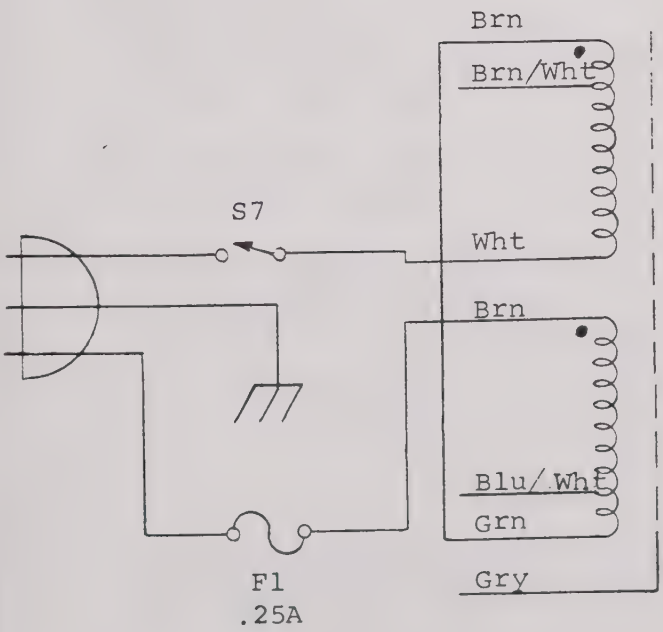


FIGURE 5.2C
230V Connection
Jumper Blu/Grn to Brn/Wht



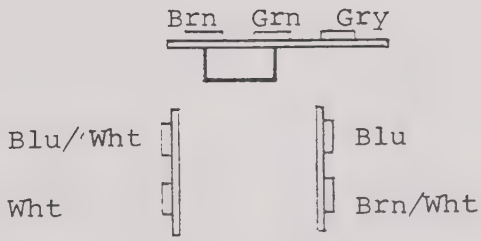


FIGURE 5.2D
250V Connection
Jumper Brn to Grn

1/16/67

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SECTION VI

TEST AND ALIGNMENT PROCEDURE

It is the purpose of this procedure to assist a qualified technician in the recalibration of the Model 214 Phase Angle Voltmeter. Under normal circumstances, this instrument, due to the use of solid-state circuitry, should require a minimum of service and recalibration.

The Test Procedure portion of Section VI may be used for incoming acceptance test or for periodic calibration checks. It is recommended that the initial periodic check be made every 3 months and future checks be expanded to 5 months or yearly checks.

The Alignment Procedure portion of Section VI may be used for recalibration in the event there is a failure which requires the replacement of any module or component in the instrument.

EQUIPMENT REQUIRED

1. Variable Voltage Source
   Frequency Accuracy: ±5%
   Frequency Range: 10Hz to 100KHz
   (e.g., - Elin AD0102)

2. Scale Voltmeter, Monitor
   Accuracy: ±.5% calibrated full scale - 400Hz.

3. Frequency Response Voltmeter, Monitor
   Flat Frequency Response: ±.5%, 10Hz to 100KHz
   (e.g., Hewlett-Packard Model 739AR)*

4. North Atlantic Industries Model RB-503 AC Ratio Box

*A Hewlett-Packard K02-738BR VTVM calibration system may be used in place of the above equipment.

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I. Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

B. Ground Isolation Check (instrument turned off):

1. Check resistance between chassis ground and circuit ground at the signal input terminals. (Link must be removed). This should read open.

C. Noise Check (instrument on, chassis connected to house ground, ground link in place):

1. Short SIGnal input terminals, apply a 100V REFerence signal and set reference to red line.

2. Reading on the meter should not exceed 15uv on any range in the TOTAL and FUND Modes. In the PAV (Phase Sensitive Modes, the meter indication should be less than 2uv).

II. Voltage Check - Connect instrument as shown in Figure 6.3a

A. Set controls as follows:

FREQUENCY Switch - any operating frequency
FUNCTION Switch - Total
TRANS/DIR Switch - DIR (Model 214C only)

B. Apply a voltage to the SIGnal input terminals corresponding to the full scale indication at each position of the RANGE Switch. The accuracy of the input voltage should be ±0.5%. The Model 214 should indicate these values ±2% of full scale.

1. Set RANGE Switch to 300uv.

2. Apply a 300uv ± .5%, 400Hz to the SIGnal input terminals.

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3. Meter should now read 300uv ± 2%.

4. Set RANGE Switch to 1mv.

5. Apply a 1mv, ±.5%, 400Hz to the SIGnal input terminals.

6. Meter should now read 1mv ± 2%.

7. Set RANGE Switch to 3mv.

8. Apply a 3mv ± .5%, 400Hz to the SIGnal input terminals.

9. Meter should now read 3mv ± 2%.

10. Set RANGE Switch to 10mv.

11. Apply a 10mv ±.5%, 400Hz to the SIGnal input terminals.

12. Meter should now read 10mv ± 2%.

13. Set RANGE Switch to 30mv.

14. Apply a 30mv ±.5%, 400Hz to the SIGnal input terminals.

15. Meter should now read 30mv ± 2%.

16. Set RANGE Switch to 100mv.

17. Apply a 100mv ± .5%, 400Hz to the SIGnal input terminals.

18. Meter should now read 100mv ± 2%.

19. Set RANGE Switch to 300mv.

20. Apply a 300mv ±.5%, 400Hz to the SIGnal input terminals.

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21. Meter should now read 300mv ± 2%.

22. Set RANGE Switch to 1V.

23. Apply a 1V ± .5%, 400Hz to the SIGnal input terminals.

24. Meter should now read 1V ± 2%.

25. Set RANGE Switch to 3V.

26. Apply a 3V, ±.5%, 400Hz to the SIGnal input terminals.

27. Meter should now read 3V ± 2%.

28. Set RANGE Switch to 30V.

29. Apply a 30V ± .5%, 400Hz to the SIGnal input terminals.

30. Meter should now read 30V ± 2%.

31. Set RANGE Switch to 100V ±2%.

32. Apply a 100V ±.5%, 400Hz to the SIGnal input terminals.

33. Meter should now read 100V ± 2%.

34. Set RANGE Switch to 300V.

35. Apply a 300V ± .5%, 400Hz to the SIGnal input terminals.

36. Meter should now read 300V ± 2%.

C. Switch the FUNCTION Switch to FUND and repeat B (Signal input must be at the frequency indicated by the FREQUENCY Switch).

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D. (Model 214C instruments only) -

Switch the TRANS/DIR Switch to TRANS. With FUNCTION Switch in FUND position and a signal at the frequency indicated by the FREQUENCY Switch, repeat Step B.

E. Linearity Check -

Set the FREQUENCY Switch to any convenient frequency and inject a full scale signal into the SIGnal input terminals. Switch the FUNCTION Switch to FUND. Change input SIGnal down scale in discrete steps. Meter should indicate corresponding levels as follows (±2%):

Range	Input	Meter X Full Scale
1V	1V	1
1V	.8V	.8
1V	.6V	.6
1V	.4V	.4
1V	.2V	.2
1V	.1V	.1

III. Frequency Response - TOTAL Mode, DIR only in Model 214C

A. Set FREQUENCY Switch to any frequency.
Set FUNCTION Switch to TOTAL.
Set RANGE Switch to 0.1V.
Set TRANS/DIR Switch to DIR (Model C only)

B. Using a wide band oscillator, inject a signal equal to .09V at 400Hz. Monitor this input voltage with a meter which has a known frequency response which is flat to within 0.5% over a range of 10Hz to 100KHz.

C. Sweep the input signal from 10Hz to 100KHz. Meter should indicate .09V ± 2% over this range.

D. Switch RANGE Switch to 1.0V. Reset input level to .9V at 400Hz and repeat Step C. Meter should indicate .9V ± 2% over this frequency range.

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IV. Phase Check

The following checks should be made at all active channel frequencies. For methods of generating phase angles, see Page 6.7.

A. Set FREQUENCY Switch to desired frequency.

B. Using a 10V voltage level into the REFerence input terminals, set FUNCTION Switch to REF ADJ position and set HI-LO Switch and variable Reference Adjust control to cause the meter to read "red line" (red mark at half scale on meter).

C. Set FUNCTION Switch to 90°.
Set Phase Dial to 0°.
Set RANGE Switch to .001V.

D. Inject a .010V (10 x overload) 0° signal into the SIGnal input terminals.

E. Adjust Phase Dial to cause the meter to read a null (0). The indicated angle should be ±1° of the input angle, (i.e., with a 0° input, the Phase Dial should read between -1° and +1° which is ± 2 divisions).

F. Repeat Steps D and E in 10° increments to 90°. The Phase Dial readings should all be within ± 1° of the input signal angle.

V. OVERLOAD Check

A. Set FREQUENCY Switch to any convenient frequency.

B. Inject a REFerence signal at the frequency of operation and adjust the reference level as in IV-B.

C. Set the FUNCTION Switch to 90°.
Set the RANGE Switch to .1V.

D. Inject a 0° signal into the SIGnal input terminals, at approximately 1V level (10 x overload). Meter will indicate zero.

E. Gradually increase the input signal until OVERLOAD light comes on. This should occur at approximately 11 x overload (1.1V).

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VI. Phase Angle Generation

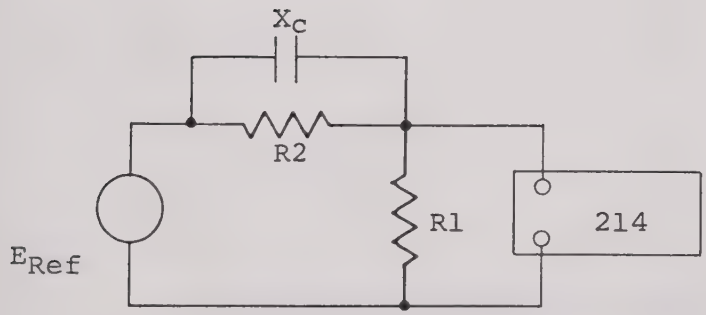
The test procedure requires that phase angles other than 90° or 0° be used for some checks. Commercially available phase angle generating equipment may be used to perform these tests. However, if commercial equipment is not available, it is suggested that the following methods be used.

RC Passive Phase Shifter - Precise phase angles can be generated using the circuit configuration shown below. These networks are very useful and are simple to construct. They do require, however, accurate measurement of component values. They may be constructed with the aid of the design equations shown below. The components should be high quality, stable devices; such as, mica or polystyrene capacitors, and metal film or deposited carbon resistors.

$$\text{Attenuation} = \frac{R_1}{|Z|}$$

$$\text{Phase Shift} = \text{Tan}^{-1}\ \frac{R_2}{X_C}$$

Providing $R_1 \angle \angle |Z|$



$$Z = \frac{R_2}{1+j\ \frac{R_2}{X_C}}$$

$$|Z| = \frac{R_2 X_C \sqrt{X_C{}^2+R_2{}^2}}{X_C{}^2 + R_2{}^2}$$

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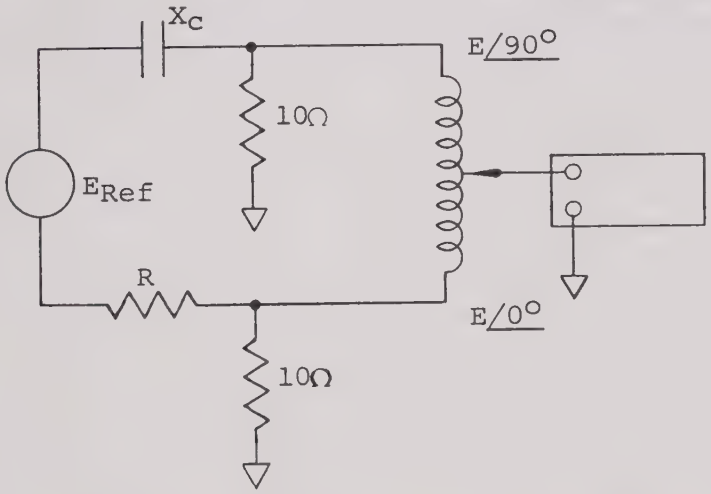
Ratio Box Phase Shifter - This circuit is somewhat less complicated than the previous circuit in that it requires only a precise 0° and 90° signal be generated by use of passive networks but it does require that a high quality Ratio Box which is accurate at the operating frequency be used. The components again must be high quality and drift free. It may be seen that any angle between 0° and 90° can be selected depending on the setting of the Ratio Box. It should be noted, however, that the amplitude of the 0° and 90° signal should be set equal to each other. The output amplitude will vary through a minimum of 0.707 of the 0° and 90° signals at 45° (Ratio Box setting of 0.5).

Phase network component values and Ratio Box settings are determined by the equations shown.



$$\frac{X_C}{10} \gg 1000$$

$$R = X_C$$

$E/0^{\circ}$ and $E/90^{\circ}$ must be set equal within 1/4%.

Ratio Box setting = $\frac{1}{1+\text{ctn}\theta}$ where θ is desired phase shift.

Resolver Simulator Phase Shifter - The third system is that of the resolver simulator phase shifter. This circuit very closely simulates the performance of the resolver in that the phase angle generated is between 0° and 90° at a constant amplitude. The same passive networks as above are used to generate the 0° and 90° and also as above their amplitudes must be set equal to each other. Two Ratio Boxes are used to drive a bridging transformer. The 0° and 90° signals of varying amplitudes as set by the Ratio

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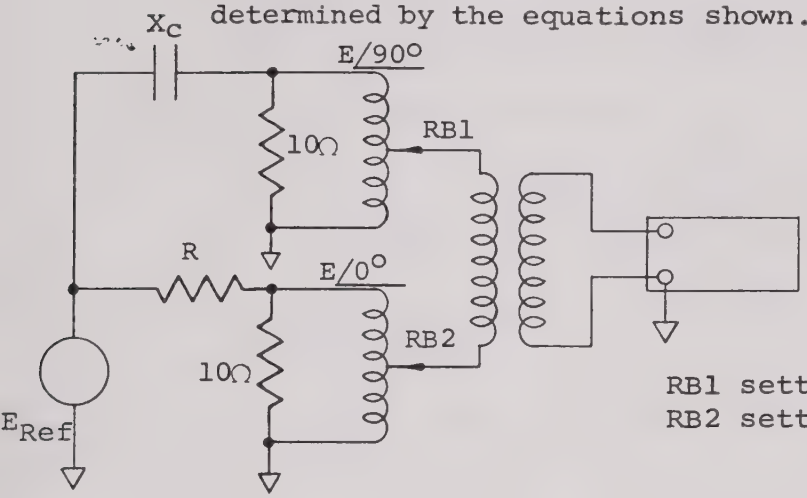
Boxes are then summed vectorally in the bridging transformer and the resultant output is fed to the Model 214. Phase network component values and Ratio Box settings are determined by the equations shown.



$$\frac{X_C}{10} \gg 1000$$

$$R = X_C$$

E/0° and E/90° must be set equal within 1/4%.

RB1 setting = sin θ
RB2 setting = cos θ
} where θ is desired phase shift.

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I. Preliminary Checks

A. Before turning on equipment, check mechanical zero of the meter and rezero if necessary.

B. Ground Isolation Check:

1. Check resistance between chassis ground and circuit ground at the signal input terminals (link must be removed). This should read open.

C. Power Supply Check - Instrument turned on (RANGE Switch on 300V Range).

1. Check Pins C, D, and P of J6. Each should read +30V ± 1.5V.

2. Check ripple with Hewlett-Packard voltmeter. Should not exceed the following:

Pin C	7mv RMS
Pin D	7mv RMS
Pin P	85mv RMS

D. Noise Check:

1. Short SIGnal input terminals, apply a 100V reference signal.

2. Reading on the meter should not exceed 15uv on any range in the TOTAL and FUND Modes. In the PAV (Phase Sensitive) Mode, the meter indication should be less than 2uv.

II. Voltage Alignment - Connect as in Figure 6.3a

The following adjustments are for the purposes of calibrating the basic voltage gain of the instrument, plus setting the transfer of the filters in the additional channels. It also incorporates the "broadband" adjustment of the 1000:1 standard input attenuator and the TOTAL Mode frequency response trim.

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A. FUND Adjustment

1. Set RANGE Switch to 0.1V, FUNCTION Switch to FUND, and FREQUENCY Switch to "Channel A" frequency (ccw frequency position).

2. Apply 0.1V at "Channel A" frequency to the SIGnal input terminals.

3. Adjust R11 Adj. Pot for full scale indication on the meter.

4. Set the FREQUENCY Switch to Channel "B", "C", and "D" if used and apply 0.1V at each frequency in turn. Adjust R7-B, C, and D for each respective channel to cause a full scale indication on the meter in each case.

B. TOTAL Adjustment

1. Rotate FUNCTION Switch to TOTAL position and FREQUENCY Switch to Channel "A". Apply 0.1V at 400Hz and adjust R1 for a full scale reading on the meter.

C. REFERENCE HI-LO Adjustment

The following procedures are for aligning the high level reference attenuator. This attenuator must operate over the entire frequency range of the instrument. It must, therefore, be adjusted for a "flat" amplitude characteristic and minimum phase shift over the entire frequency range. It may be adjusted by two different methods as follows:

1. For instruments which include frequencies between 160Hz and 1KHz

   a. Set the FREQUENCY Switch to a frequency between 160Hz and 1KHz (closest to 400Hz) (TRANS/DIR Switch to DIR in Model 214C instruments).

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b. Set the REFERENCE HI-LO Switch to LO and the variable Reference Adjust Control to minimum (counterclockwise).

c. Set the FUNCTION Switch to the REF ADJ position. Apply a voltage (at the proper frequency) to the REFerence input terminals. Adjust this reference input voltage to cause the meter to read at "red line" (half scale) on the meter

d. Apply the same signal to the SIGnal input terminals with the RANGE Switch in the 0.3V position for Model 214A or 10V Range for Models 214B and 214C (approximately 10 x overload).

e. Set the FUNCTION Switch to the 90° position and rotate the Phase Dial until the meter reads zero. (The Signal and Reference Channels have now been adjusted arbitrarily so that zero phase shift exists between them).

f. Set the REFERENCE HI-LO Switch to the HI position and the FUNCTION Switch to REF ADJ, and rotate the variable Reference Adjust control to cause the meter to read "red line" (Half scale).

g. Set the FUNCTION Switch to 90° position and adjust C6 (3-12uuf trimmer capacitor) to cause a zero reading on the meter. (Capacitor C6 is located behind the front panel near the reference input terminals. It may be reached easily by removing the instrument's top cover.)

h. Repeat Steps "a" through "g" at all phase sensitive operating frequencies. Do not readjust C6. This is to check performance of the attenuator. If any errors exceed ± .25°, a malfunction is indicated.

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2. For instruments which do not include frequencies between 160Hz and 1KHz

a. Set the REFERENCE HI-LO Switch to HI and the FUNCTION Switch to the REF ADJ position.

b. Apply a 100Hz signal to the REFerence input terminals.

c. Adjust the variable reference control to cause the instrument to read full scale.

d. Using a meter with a frequency response which is flat within ±.5% fron 100Hz to 10KHz, monitor and note the input voltage. (For Model 214B and 214C instruments, this voltage must be monitored at terminals H and J of T4).

e. Reset the input signal to 10KHz and readjust the level to precisely the same input voltage applied at 100Hz (as noted in d above).

f. Adjust C6 to cause the meter to read full scale. The reference attenuator is now "broadbanded" and will have minimal phase shift.

D. 1000:1 Standard Input Attenuator Adjustment

The 1000:1 input attenuator requires an adjustment which is similar to the one just made in Step C above. This attenuator is used not only for phase sensitive operation but also for TOTAL Mode and therefore, will operate over an event wider range of frequencies. Two different methods may also be used to adjust this attenuator.

1. For instruments which include frequencies between 160Hz and and 1KHz (Connect instruments as shown in Figure 6.3a).

a. Set voltage source for precisely 10V as measured on the Monitor Voltmeter at a frequency corresponding to the Model 214 frequency closest to 600Hz.

b. Set Ratio Box to .01V (.001000).

c. Set FUNCTION Switch to REF ADJ. Adjust variable reference control for "red line". (Reference HI-LO Switch set to HI for Model 214 and to LO for Models 214B and C)

d. Set RANGE Switch to .001V, FUNCTION Switch to 90°, FREQUENCY Switch to above-mentioned frequency, TRANS/DIR Switch to DIR.

e. Rotate Phase Dial until meter reads precisely zero.

f. Set RANGE Switch to 10V position and FUNCTION Switch to FUND.

g. Set Ratio Box for 10V (1.00000).

h. Adjust R106 for full scale reading on 214 meter. See Figure 6.1.

i. Set FUNCTION Switch to 90° and RANGE Switch to 1V (10 x overload).

j. Adjust C101 for zero reading on 214 meter. See Figure 6.1

k. Repeat Steps f through j until best results are obtained. This is required due to the interaction of the two controls.

2. <u>For instruments which do not include frequencies between 160Hz and 1KHz</u>

a. Set the RANGE Switch to the 1V position, the FUNCTION Switch to TOTAL, the FREQUENCY Switch to any frequency position. (In the Model 214C instruments, DIR/TRANS Switch to DIR.)

b. Apply a 1V ± .5%, 100Hz signal to SIGnal input terminals, monitor with meter which has a frequency response flat within ±.5%.

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c. Adjust R106 for full scale reading on meter. See Figure 6.1.

e. Adjust C101 for a full scale reading on the meter. See Figure 6.1.

F. Recheck Steps b through ē, readjusting as necessary. The 1000:1 attenuator is now "broadbanded" and will have minimal phase shift.

D. Frequency Response Trim (TOTAL MODE)

The Frequency Response of the 214 in the TOTAL MODE should not require retrimming unless an amplifier is replaced. Note that in Model 214C instruments, in the TRANS position of the DIR/TRANS Switch, the frequency response is limited to that of the transformer.

1. Set the FUNCTION Switch to TOTAL, the FREQUENCY Switch to any frequency position, the RANGE Switch to .01V, and in Model 214C instruments, set the DIR/TRANS Switch to DIR.

2. Using the wide band voltage source, inject a .009 volts signal (90% of full scale) at 400Hz. Note reading.

3. Check this reading at 100KHz.

4. If the error observed exceeds ±2% of full scale of the initial reading, it may be corrected by selecting a new value for C10 or C12 and R15. See Figure 3.2.

5. Check the reading at 10Hz.

6. If the error observed exceeds ±2% of full scale of the initial reading, it may be corrected by selecting a new value for C105. See Figure 3.2

III Phase Dial Alignment on Phase Shifter Pot, R8. (This should be checked before proceeding with Phase Alignment.)

The following is a procedure for mechanically aligning the Phase Dial on the shaft on the Phase Shifter pot, (R8). This is necessary in the event that a Phase Dial, phase pot, or both are disassembled or replaced. The 0° and 90° points on the Phase Dial must be applied to coincide with the taps (terminals 4 and 5) of the pot.

CAUTION: Use only a high impedance ohmmeter (i.e., H.P. 412) as damage to the precision phase pot can occur if excessive voltage is applied.

A. Turn power off.

B. Set FUNCTION Selector to any phase sensitive position.

C. Use an ohmmeter to place the wiper of R8 exactly on the ccw tap point (terminal 4). Loosen dial clamping screw and rotate Phase Dial until dial reading is exactly 90°. Tighten clamping screw. Reconnect ohmmeter to cw tap point and rotate Phase Dial until wiper of R8 is on cw (terminal 5) tap point. Dial should now read zero degrees. If not, reposition dial so as to achieve the best compromise reading between the two taps. For example, if the zero degree point reads low, the 90° point should read high by the same amount. Fully tighten set screw and recheck to make sure dial has not slipped during tightening.

IV. Phase Alignment

This alignment will adjust the instrument for zero phase shift between the signal and reference channels.

A. Connect the Model 214 as shown in Figure 6.3b. This will require a precise 90° phase shifted signal which may be generated as indicated in this figure.

B. Set FREQUENCY Switch to the frequency to be calibrated.

C. Set FUNCTION Switch to REF ADJ, inject 100V at the frequency of operation into the REFerence input terminals. Adjust variable reference controls for "red line" on the meter.

D. Set the FUNCTION Switch to 0°, Phase Dial to 0°, and RANGE Switch to .01V.

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E. Connect the precise 90°, .01V signal to the SIGnal input terminals.

F. Set RANGE Switch to .001V (10 x overload) and adjust R23-A, B, C, or D (See Figure 6.1) as the case may be to cause the meter to read 0.

G. Set FUNCTION Switch to 90° and Phase Dial to 90°.

H. If an error exists, readjust R23-A, B, C, or D to divide the error between Steps F and G.

V. Alternate 1000:1 Attenuator Adjustment (Model 214C)

The following is the proper procedure for adjusting the alternate 1000:1 attenuator in those instruments that contain frequency channels under 400Hz or for special input requirements.

A. Connect the 214 as for voltage alignment.

1. Set the RANGE Switch to 10V.

2. Set the FUNCTION Switch to TOTAL.

3. Set the FREQUENCY Switch to a channel with a frequency of 400Hz or less.

4. Inject a 10V, 400Hz signal into the SIGnal input terminals.

5. Adjust R103 (located on RANGE Switch S1, see Figure 6.1) to cause the instrument to read full scale.

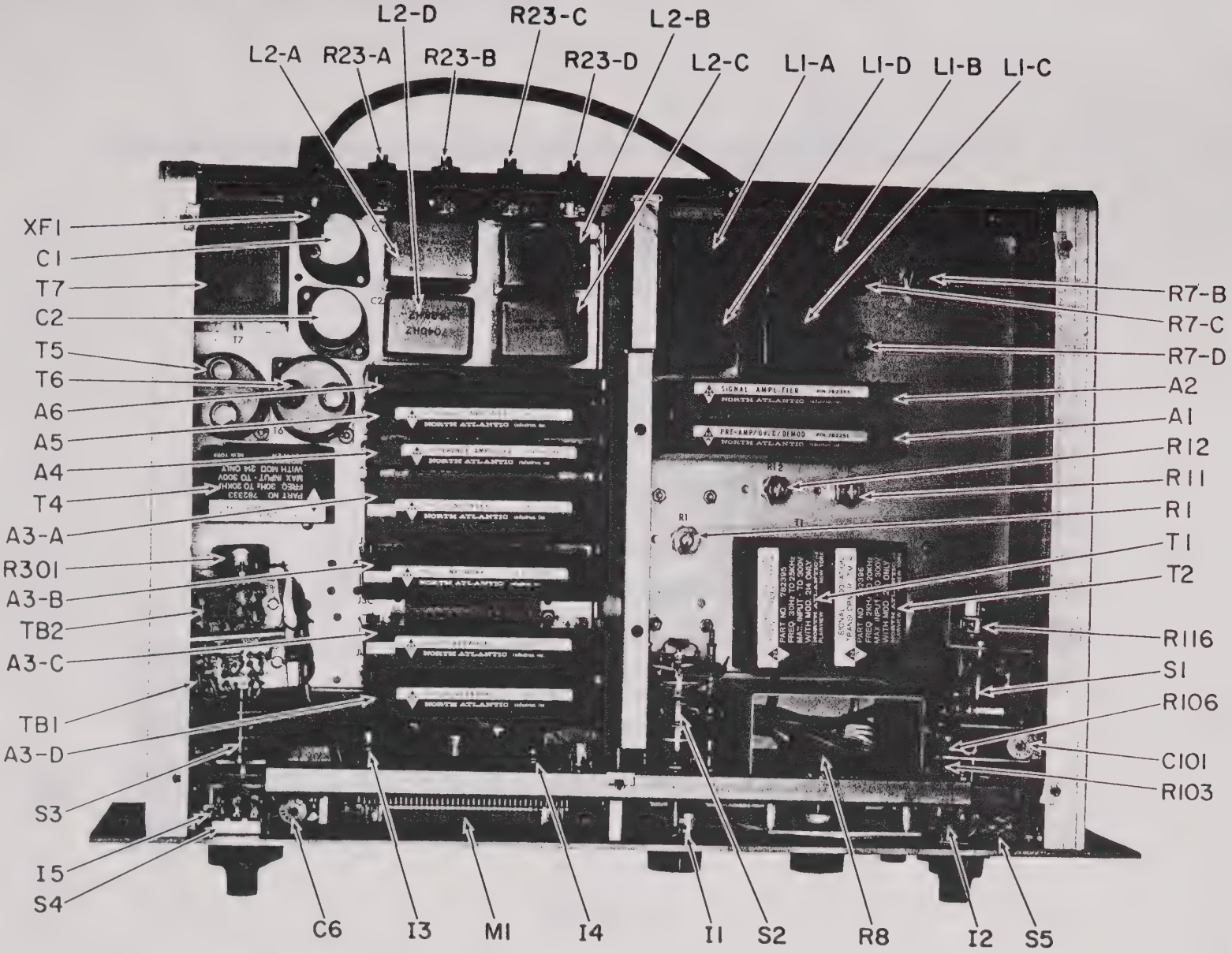


FIGURE 6.1

TOP VIEW, MODEL 214C

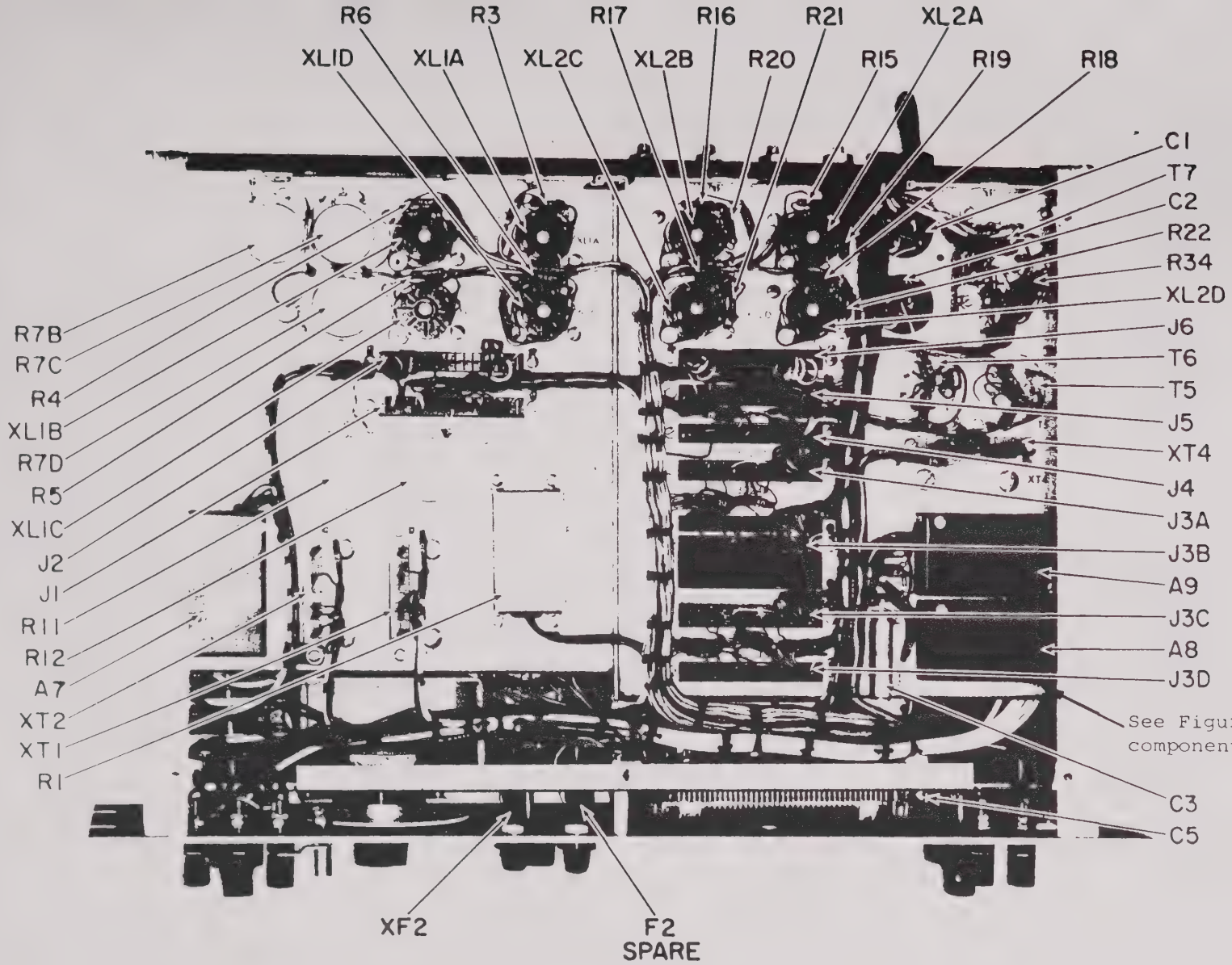
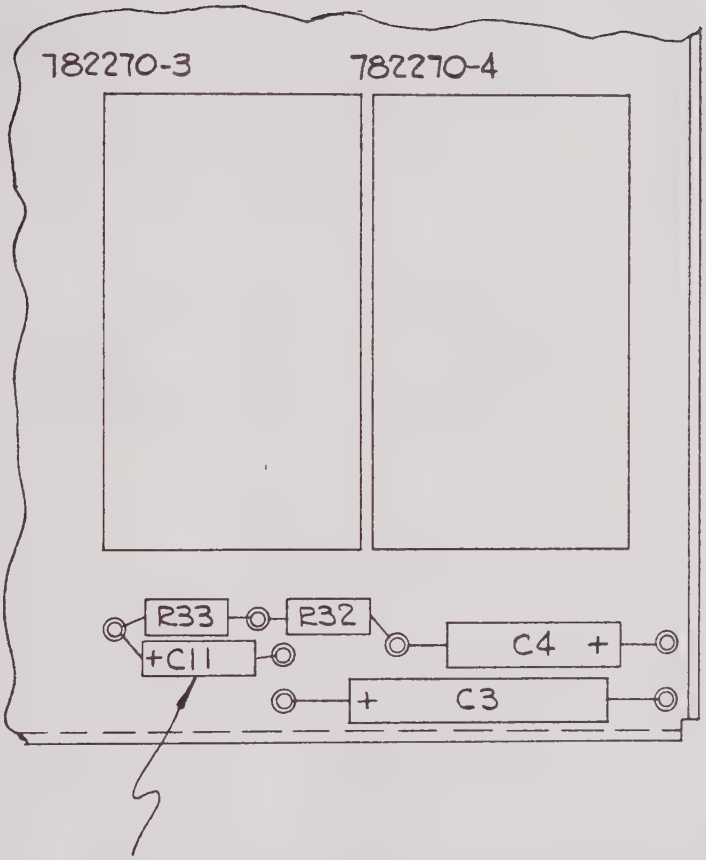


FIGURE 6.2

BOTTOM VIEW, MODEL 214C



Used for frequencies below 60Hz only.

This component arrangement exists in most instruments. Some earlier instruments were supplied as shown in Figure 6.2.

Figure 6.2a

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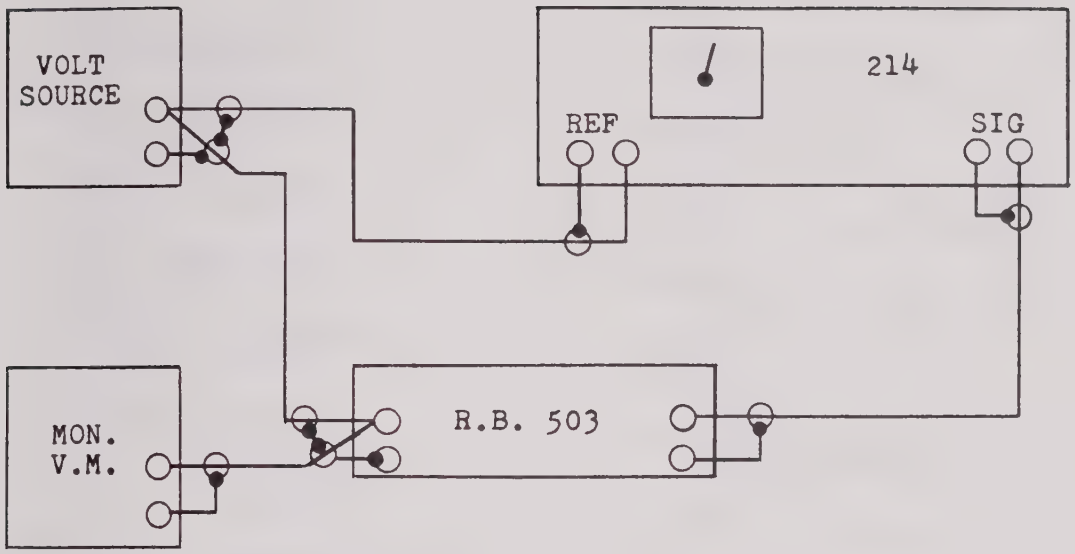

Figure 6.3A

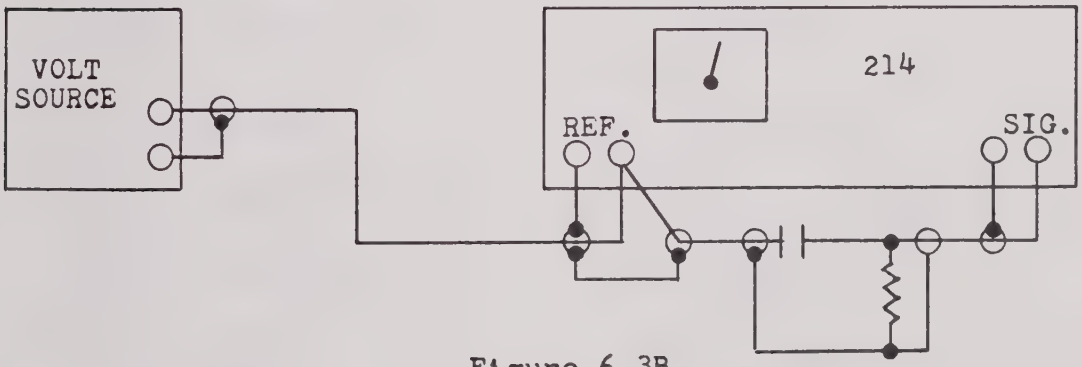

Figure 6.3B

400Hz

C = 500pf

R = 80 ohms

For other frequencies

X_C approx. 10000 times R

R less than 200 ohms

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WARRANTY

A. North Atlantic Industries, Inc. warrants the Product(s) against defects in material and workmanship for one year from the date of original shipment. The Seller's liability is limited to the repair or replacement of the Product(s) which proves to be defective during the Warranty period.

B. North Atlantic Industries, Inc. specifically excludes from the Warranty,

1) Fuses and electron tubes.

2) Mechanical wear associated with normal operation of the Product(s). Life characteristics of mechanical assemblies such as switches, relays, and gear trains are based upon actual operating conditions, and end-of-life can occur within the Warranty period. The Seller's instruction manual or data sheet shipped with the Product(s) will normally notify the Purchaser of life related parts or assemblies.

3) Recalibration of the Product(s).

C. North Atlantic Industries, Inc. is not liable for consequential damages or for any injury or damage to persons or property resulting from the operation or application of the Product(s).

D. The Warranty is voided if there is evidence that the Product(s) has been operated beyond its design range, improperly maintained or physically mistreated.

E. In the event of malfunction in the Product(s) under Warranty, the Purchaser should notify the Seller's local Sales Representative or the Seller's Marketing Services Department giving full details of the defect and providing the model and serial number (if applicable) of the Product(s). Service data, corrective action, or shipping instructions will be forwarded promptly. There is no charge for Warranty repair of the Product(s) except for transportation charges. However, the Purchaser shall be responsible for the Product(s) shipped until received by the Seller.

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F. North Atlantic Industries, Inc. reserves the right to make changes and improvements to the Product(s) without any liability for incorporating such changes or improvements in any Product(s) previously sold, or for any notification to the Purchaser prior to shipment. In the event the Purchaser should require subsequently manufactured lots of the Product(s) to be identical to the equipment delivered in this order, the Seller will, upon written request, provide a quotation upon a change control program.

G. No other Warranty expressed or implied is offered by the Seller other than the foregoing.

CLAIMS FOR DAMAGE IN SHIPMENT

The purchaser should inspect and functionally test the Product(s) in accordance with the instruction manual as soon as it is received. If the product is damaged in any way, including concealed damage, a claim should be filed immediately with the carrier, or, if insured separately, with the purchaser's insurance company.

SHIPPING

On products to be returned under warranty, await receipt of shipping instructions, then forward the instrument prepaid to the destination indicated. The original shipping containers with their appropriate blocking and isolating material is the preferred method of packaging. Any other suitably strong container may be used providing the product is wrapped in heavy paper or a plastic bag and surrounded with at least four inches of shock absorbing material to cushion firmly, preventing movement inside the container.

APPLICATION NOTES

FOR

SERIES 200

PHASE ANGLE VOLTMETERS

The North Atlantic Industries Series 200 Phase Angle Voltmeter is a truly unique, multifunctional instrument which will function as a sensitive voltmeter, a phase angle meter, a meter measuring in-phase signals (E cos θ), and quadrature signals (E sin θ), a phase sensitive null indicator, an impedance meter, and a power factor meter.

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I - INTRODUCTION

The following notes will acquaint the user of the 200 Series Phase Angle Voltmeter with the many ways in which these versatile instruments can be used.

By virtue of the instrument's ability to measure the two basic characteristics of any signal; namely, magnitude and phase angle, measurements are now possible which previously either required extensive associated equipment or could not be made at all.

The principle of operation is illustrated in Figure (1).

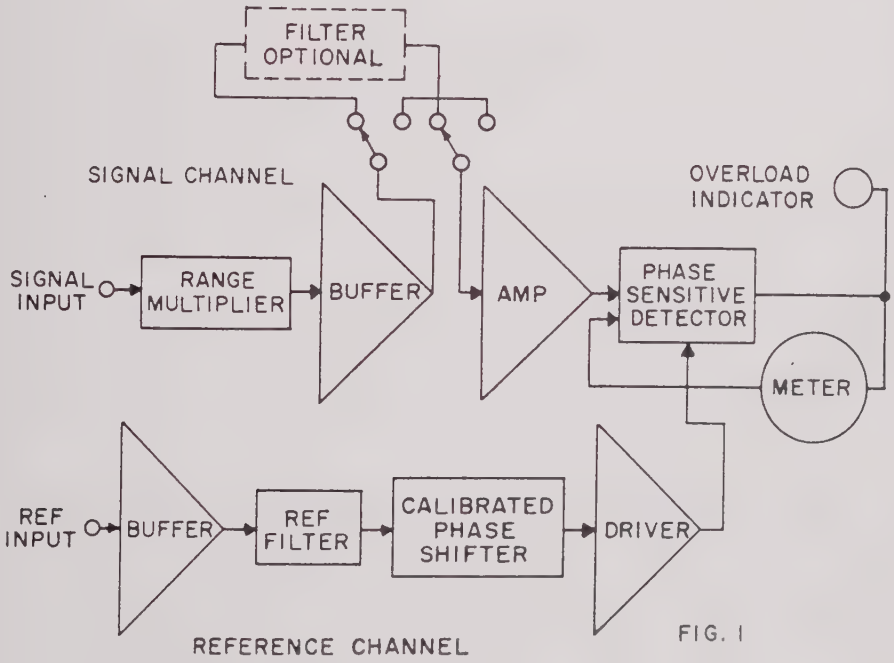

FIG. 1

An input signal is first attenuated by the range multiplier. The high gain amplifier drives a phase sensitive detector which in turn drives the indicating meter. The meter output is recombined to form an AC signal which is fed back to the amplifier input thus making the instrument independent of diode characteristics and tube ageing. A reference signal is also amplified and its phase angle shifted by the calibrated phase shifter. This signal driving the phase sensitive detector results in the phase angle characteristics shown in Figures (5) and (6).

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The sections to follow describe the many ways in which this instrument is being used. Block diagrams illustrate typical measuring set ups.

II - GENERAL NOTES ON GROUNDING TECHNIQUES

Successful measurement with any high input impedance voltmeter is dependent upon the elimination of all unwanted or extraneous signals from the measurement circuit.

The most common sources for extraneous signals are the following:

a) Internal noise
b) Electrostatic pickup
c) Inductive pickup
d) Common ground runs

Internal noise has been minimized by design and is equivalent to less than 5 microvolts for a high impedance circuit (1.0 megohm).

Electrostatic pickup, frequency a problem in high impedance circuits, is easily eliminated by shielded cable or twisting leads one of which is at ground potential. Care must be taken, however, to avoid loading the signal source by the cable capacitance.

Inductive pickup is generally less often encountered than electrostatic pickup and possibly for that reason, methods for minimizing it are not frequently employed. Both twisted and shielded leads are effective in reducing this form of pickup because they minimize the effective area through which extraneous electromagnetic flux can pass. This is true in the case of a shielded lead, only if the shield, for example, is the return circuit for the signal.

Inductive pickup in ground leads can and does occur with multiple point grounding systems. The effect of these ground loops frequently can be reduced by bundling cables together, again so as to minimize loop areas. A better method is to eliminate the ground loops altogether especially those in the signal system or that

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portion of a circuit where a measurement is being made. Figure (2) shows several workable methods for using the voltmeter as a phase sensitive null detector when making transformation measurements. All methods can be made to work by minimizing stray fields and bundling cables together. However, Figure (2A) is the most advantageous arrangement and is not at all critical to lead runs. Figures (2B) and (2C) both have loops which can be potential trouble spots. Note also that grounds other than those shown in Figure (2) can exist due to chassis contact, line cord ground, and reference grounds. All must be considered when setting up the measuring system.

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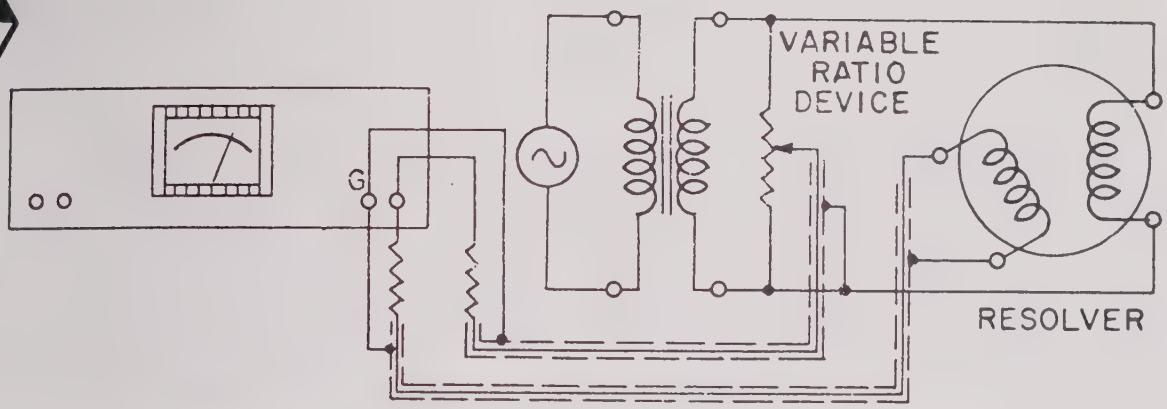
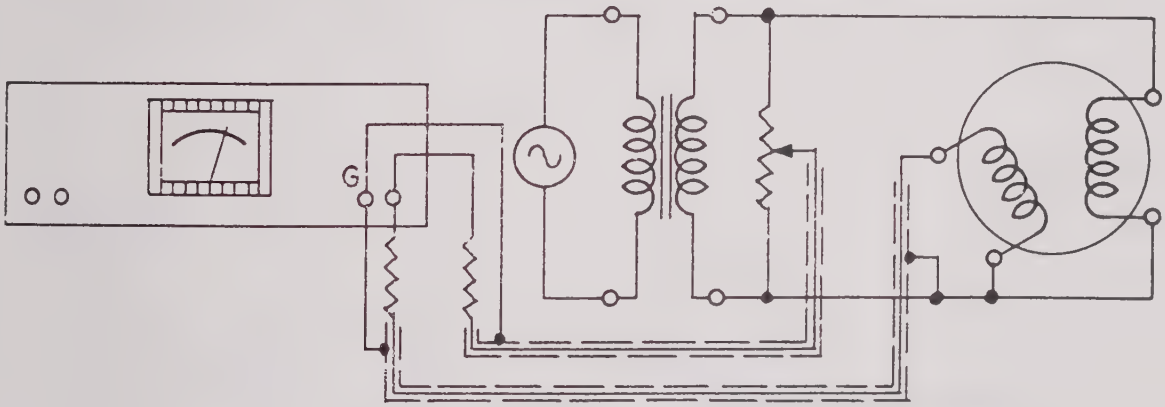
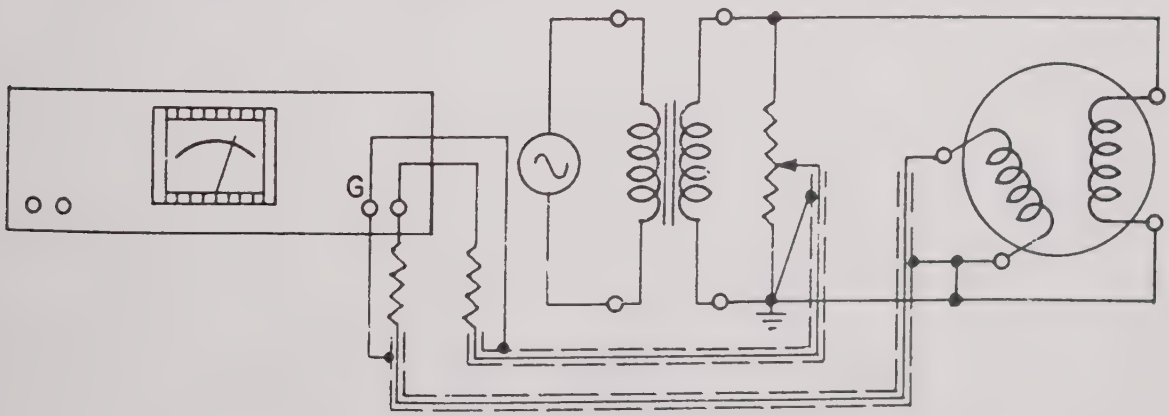


(a)—GOOD, NO LOOPS



(b)—ONE LOOP, PICK-UP POSSIBLE



(c)—POOR—ONE SIGNAL LOOP AND ONE GROUND LOOP

FIG. 2—RATIOMETER WITH SERIES SUMMING

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Common ground runs are sources of extraneous signals by virtue of voltage drops in the voltmeter input which arise from ground current other than the signal ground current. Figure (3) is a sketch of a typical arrangement wherein the power ground lead is in part that of the shield on the signal input. A portion of the load current as well as power supply leakage current to ground go through the voltmeter input cable. The voltage drop in the length of common ground is measured in addition to the signal.

Figure (3) also illustrates the internal grounding arrangement. The fact that there are four places in which a ground can be made could mean that isolation transformers are required somewhere in the measuring circuit.

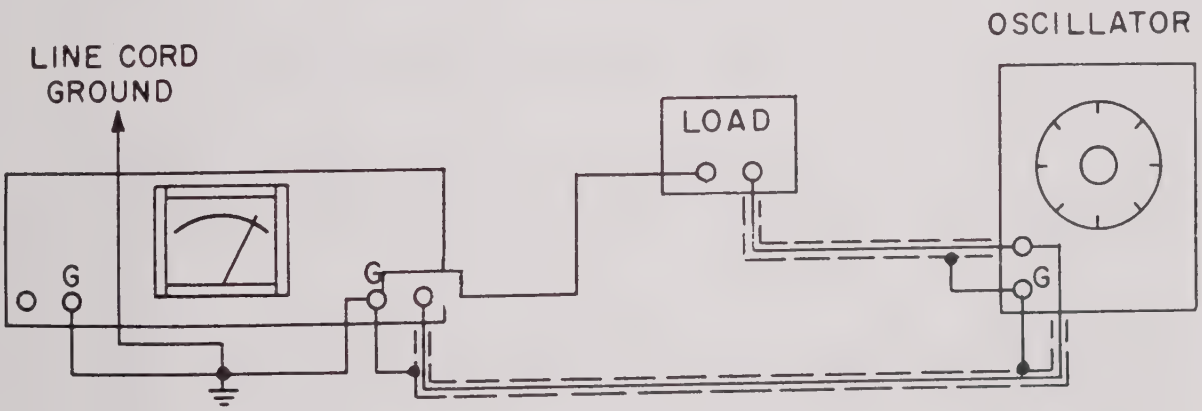

FIG. 3

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III - PHASE CHARACTERISTIC

The response of the Phase Angle Voltmeter to the fundamental frequency is given by:

(1) $E_{meter} = E_{rms} \times \cos \theta$

where E_{meter} = voltage read on the meter
E_{rms} = rms value of the input sine wave
θ = angle between the reference and signal input (Phase shifter at zero degrees)

Response to even order harmonics is theoretically zero, while odd harmonic response varies inversely with the order of the harmonic.

For example, for the 3rd harmonic equation (1) becomes:

(2) $$E_{meter} = \frac{E_{rms\ (3rd\ harmonic)} \times \cos \theta'}{3}$$

where θ' is the phase angle of the 3rd harmonic with respect to the reference.

Actually response to harmonics departs from equation (2) for a number of reasons. Since calibration of the instrument is at the fundamental frequency, measurements at frequencies other than the fundamental frequency will be somewhat in error.

For instruments having selective filters in the signal and reference channels, harmonic response will in all cases be more than 55DB down. Table I shows typical measured responses. The values shown with filters actually are the sum of the colum I data and the filter characteristic.

TABLE I

FUND (400cps)	No Signal Filter 0DB	With Signal Filter 0DB
2nd Har.	-55DB	-55DB
3rd Har.	-9.5DB	-55DB
4th Har.	-55DB	-55DB
5th Har.	-14DB	-55DB

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Measurements of phase angle using equation (1) are easily accomplished with good accuracy using the setup dhown in Figure (4). The actual phase characteristic used in the measurement is E sin θ for purpose of convenience. The procedure is to adjust accurately the θ = 90 deg. and the θ = 0 deg. point. Measurement than will be a voltage which can be directly translated into degrees using the curves of Figures (5) and (6).

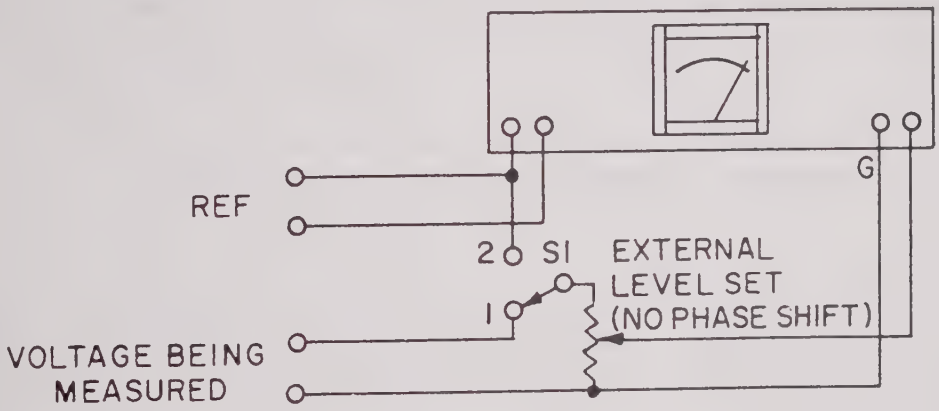

FIG. 4

The step-by-step procedure is:

1. Set reference level to red line value.

2. With meter in "STD VTVM" position and external switch S1 in position 1, select a convenient range and adjust the signal level for full scale deflection. This will insure on-scale readings. (NOTE: Any external level set should be sufficiently low in resistance so as not to introduce phase shift error.)

3. Next switch the reference into the signal channel by switching S1 to position 2 and adjust using the same external level control for full scale deflection.

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Switch the instrument to the "PHASE ANGLE VTVM" function and adjust the phase shift dial for zero meter reading. This establishes the θ = 0 deg. point or quadrature null point.

NOTE: FOR MAXIMUM ACCURACY, THIS POINT SHOULD BE RESET WHENEVER THE SCALE IS CHANGED.

4. Return the switch S1 to the signal input and readjust the full scale level with the instrument set as "STD VTVM". This establishes the θ = 90 deg. point (E maximum).

5. Switch back to the "PHASE ANGLE VTVM" position used in (3) above and read the meter. Enter the curves of Figure (5) or (6) to read degrees.

Any full scale range in degrees can be used even down to -6 deg. - 0 - +6 deg, depending upon the full scale limits. For example, if the full scale 90 degree point is set on the 1.0 volt scale and the zero point on the 3.0 volt scale, then the 3.0 volt scale will cover a range of from -17.4deg. - 0 - +17.4 deg. Table II summarizes typical setups and Figures (5) and (6) show curves which can easily be used to convert voltage measurements to degrees. These curves are actually arcsin functions. The angle can also be derived by direct computation from the voltage readings.

Errors in using this type of measurement will be a function of the scale used and the angle. In addition, for large ratios of maximum voltage to full scale values being used, saturation for a portion of each cycle can occur and will result in a small scale error. Obviously, this condition is a function of reference level and for that reason, a level of twice the red line value is recommended when using this technique.

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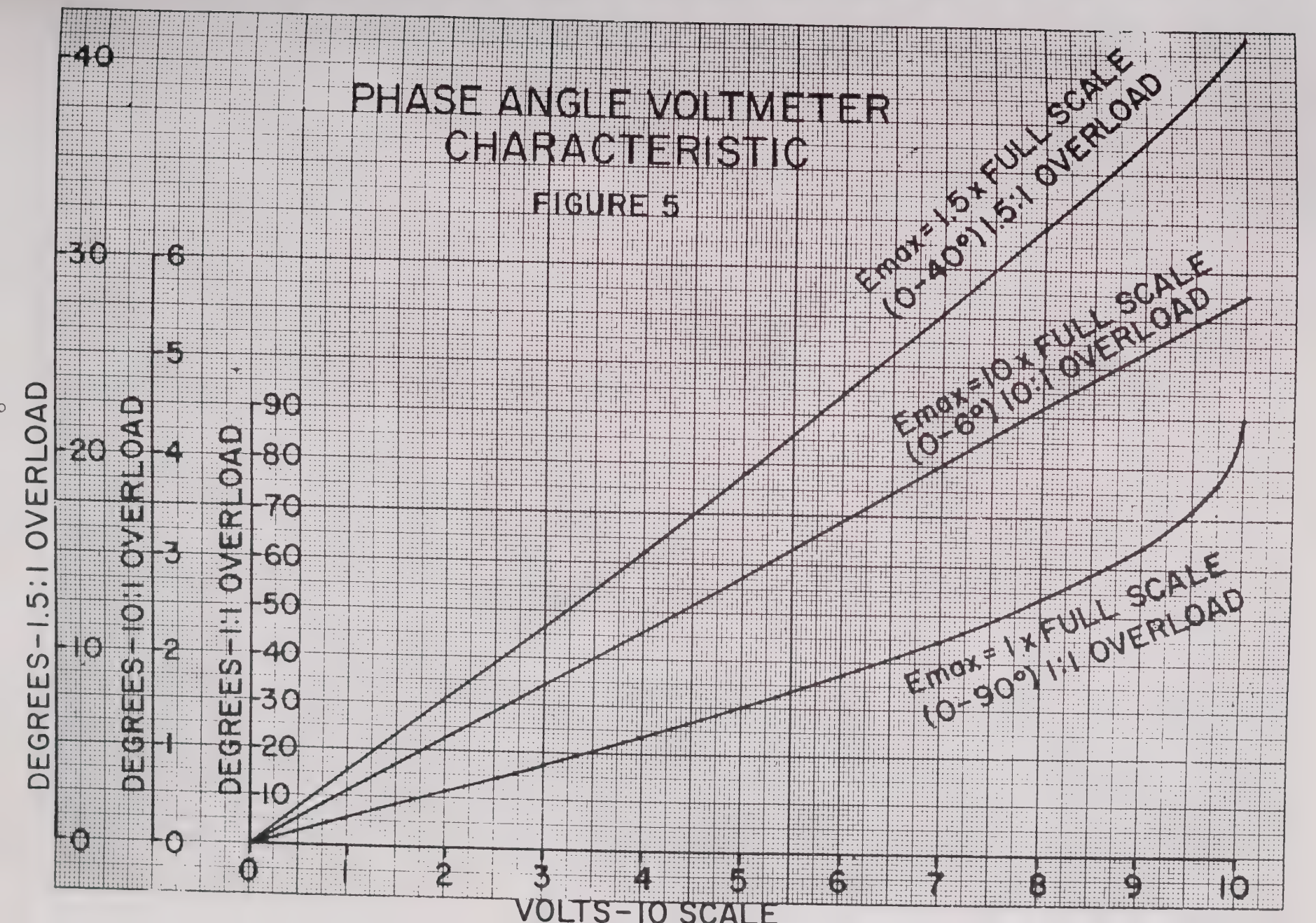
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 5
Emax=1.5 x FULL SCALE
(0-40°) 1.5:1 OVERLOAD
Emax=10 x FULL SCALE
(0-6°) 10:1 OVERLOAD
Emax=1 x FULL SCALE
(0-90°) 1:1 OVERLOAD
DEGREES-1.5:1 OVERLOAD
DEGREES-10:1 OVERLOAD
DEGREES-1:1 OVERLOAD
VOLTS-10 SCALE
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
60
70
80
90
50

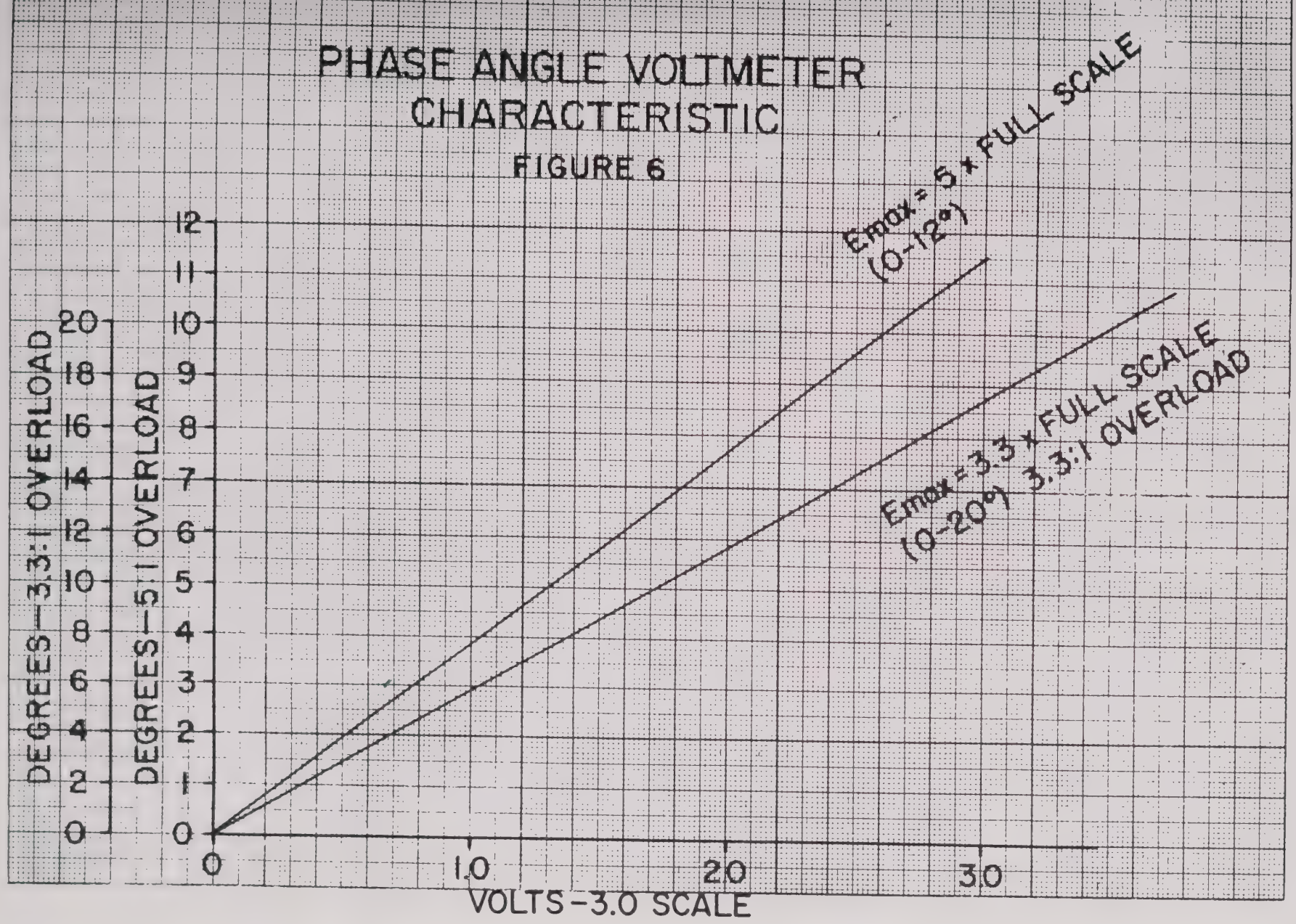
PHASE ANGLE VOLTMETER
CHARACTERISTIC
FIGURE 6
Emax = 5 x FULL SCALE
(0-12°)
Emax = 3.3 x FULL SCALE
(0-20°) 3.3:1 OVERLOAD
DEGREES—3.3:1 OVERLOAD
DEGREES—5:1 OVERLOAD
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10
11
12
0
1.0
2.0
3.0
VOLTS—3.0 SCALE

TABLE II

Maximum Voltage	Scale for Measuring Degrees	Full Scale Overload Ratio	Degree Range	Max. Error 3%	Figure
1.0	1.0	1:1	90	2.7 deg.	5
1.0	.3	3.3:1	19.5	0.6	6
1.0	.1	10:1*	5.7	.2*	5
1.5	1.0	1.5:1	41.8	1.3	5
1.5	.3	5:1	11.5	.33	6

*NOTE: The overload alarm will be lighted when operated under these conditions. Saturation errors exist and for that reason no error rating is made.

High accuracy Phase Angle Measurements to better than .01° can be made using the alternate methods discussed in Section VIII under Small Angle Measurements.

IV - PHASE ANGLE MEASUREMENTS USING CALIBRATED PHASE SHIFTER

The built-in, calibrated phase shifter can be used to measure phase angle directly simply by shifting the reference by an amount equal to the phase angle being measured so as to produce a maximum meter reading in accordance with equation (1). Precise determination of the maximum point is difficult due to the zero slope of the phase characteristic at $\theta = 0$ deg. To avoid this difficulty, the instrument is equipped with four scales 90 degrees apart. Thus, by simply switching the reference 90 degrees, the phase shifter dial can be readily set to a zero point on the meter and then by switching back to the original quadrant the unknown phase angle can be read.

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This procedure allows the measurement of phase angles from 0 to 360 degrees. Ambiguity which exists for two quadrants is easily removed by adding 180 degrees to the dial reading if a negative maximum (meter deflection to the LEFT) is used for the measurement. For positive maximums (meter deflections to the RIGHT) the dial scales apply directly.

V - MEASUREMENT OF QUADRATURE AND IN-PHASE COMPONENTS OF A SIGNAL

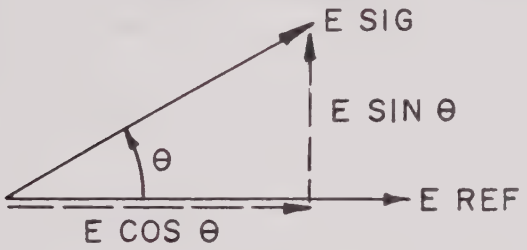

FIG. 7

The quadrature and in-phase components of a signal are defined in accordance with the diagram of Figure (7) as:

In-phase component = E cos θ

Quadrature component = E sin θ

Measurement of the in-phase component is made by placing the Phase Angle Dial at zero degrees and reading the meter directly. This voltage will be E cos θ. (Function Selector must be in one of the PHASE ANGLE VTVM positions). By switching the Function Selector to an adjacent quadrant, the reference is shifted 90 degrees and the meter now reads the quadrature component of voltage E sin θ. For the greatest accuracy in this type of measurement, the null or 90 degree point should be calibrated on the scale in which the voltage component is to be read. See the section under PHASE CHARACTERISTIC for a description of this type of adjustment.

VI - MEASUREMENT OF POWER FACTOR AND IMPEDANCE ANGLE

Both power factor and impedance angle are defined as the angle which a current vector makes with the voltage reference. This

measurement is conveniently accomplished by means of the set up shown in Figure (8). The angle is measured as previously discussed.

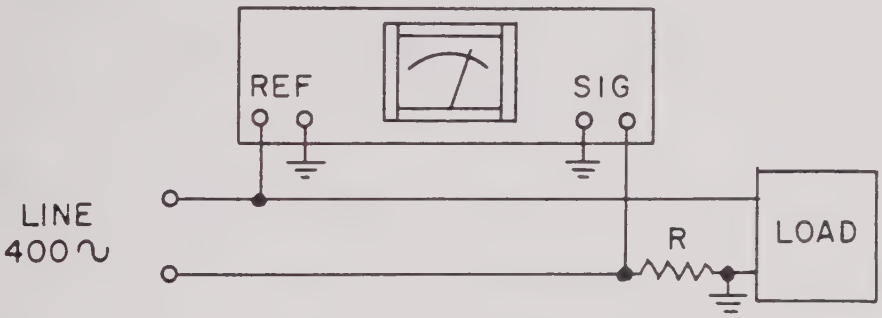

FIG. 8

VII - IMPEDANCE MAGNITUDE

The magnitude of any impedance is measured by using the "STD VTVM" portion of the instrument. Figure (9) illustrates the manner in which the measurements can be made.

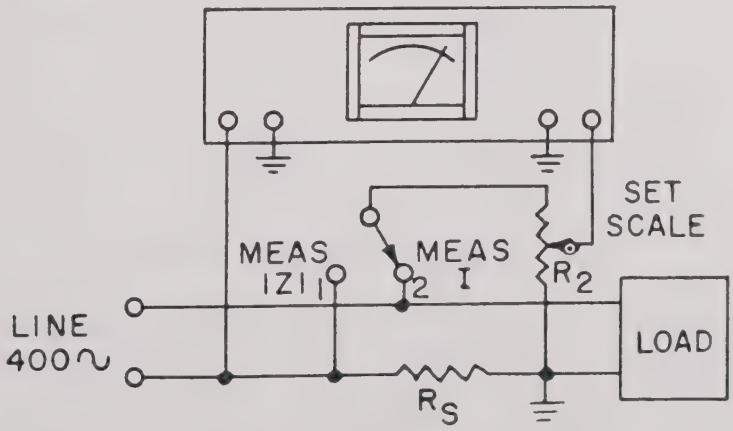

FIG. 9

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Using Table III as a guide, a precision ($\pm$ 1%) resistor of convenient size is selected for Rs. With S1 in position 1 for measuring current, adjust the scale set potentiometer to read full scale voltage on any 10 scale. Note the actual voltage value. Switch S1 to position 2 for measuring /Z/ and read the meter. This reading will be the impedance magnitude expressed in units of kilohms, ohms, hundreds of ohms, milliohms, etc. depending upon the value of Rs series resistance used per Table III and when divided by the current measurement noted above.

EXAMPLE:

Load impedance = 470K
Rs = 1K
E line = 115 volts

With S1 in position 1 set the level using R2 to a convenient full scale of 10. This might be 0.1 volts. Switching then to position S2 will produce a meter deflection of 47K on the 100K scale (100 volts scale is now 100K per Table III). Dividing this by the current scale of 0.1 will yield 470K. Since the current factor is always set at a multiple of 10, this last correction is simple to accomplish.

TABLE III

Series Resistor	Scale 1V equals	Current Factor
10K	10K	1/volts
1K	1K	1/volts
100Ω	100Ω	1/volts
10Ω	10Ω	1/volts
1Ω	1Ω	1/volts

Measurement of AC Resistance and Reactance

By using the circuit of Figure (9) the real and imaginary components of the impedance can also be measured directly by using the current as a reference and measuring the in-phase and quadrature of the signal measured with the switch in position 2. The in-phase component will be the AC Resistance and the quadrature component will be the reactance with the sign determined as positive for a

right hand meter deflection and negative for a left hand deflection.

The following series of block diagrams will illustrate how this instrument can be applied to some of the specific applications noted earlier.

VIII - APPLICATIONS

Precision Ratiometer

In many analog computer systems the process of multiplication, division, addition, and subtraction is accomplished using precision potentiometers, or resistors. Those applications involving extremes of precision must be concerned with the distributed capacitance of the circuit element. Ordinary nulling system, for example, will not permit the manufacture of very precise resistors because of the errors masked by quadrature signals. The circuit of Figure (10) permits precise zeroing of pots or matching and calibration of resistors and potentiometers independent of stray capacitances, or harmonics in the signal source.

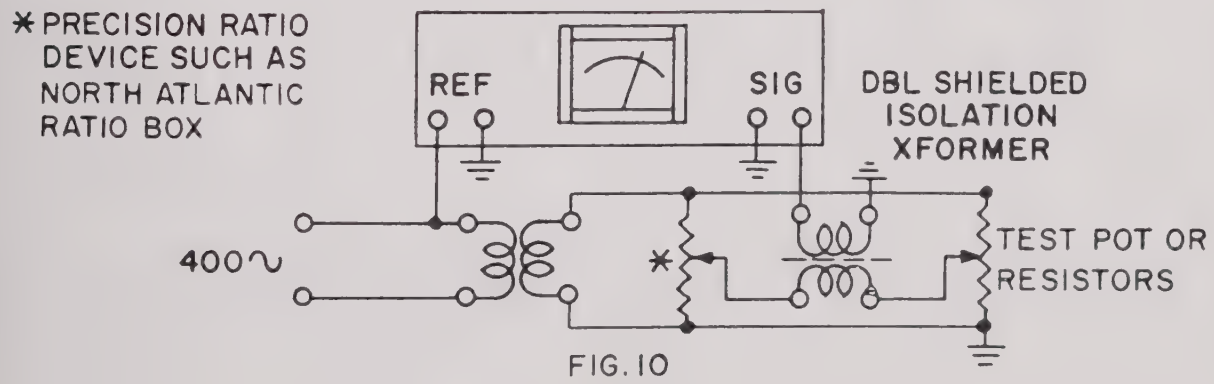

FIG. 10

Two isolation transformers are actually not necessary. If the source is to be isolated then an inexpensive transformer can be used. If the outputs are to be isolated then a low capacitance

transformer such as North Atlantic's T-110 should be used. An alternate arrangement would be the circuit of Figure 11, which uses a summing network.

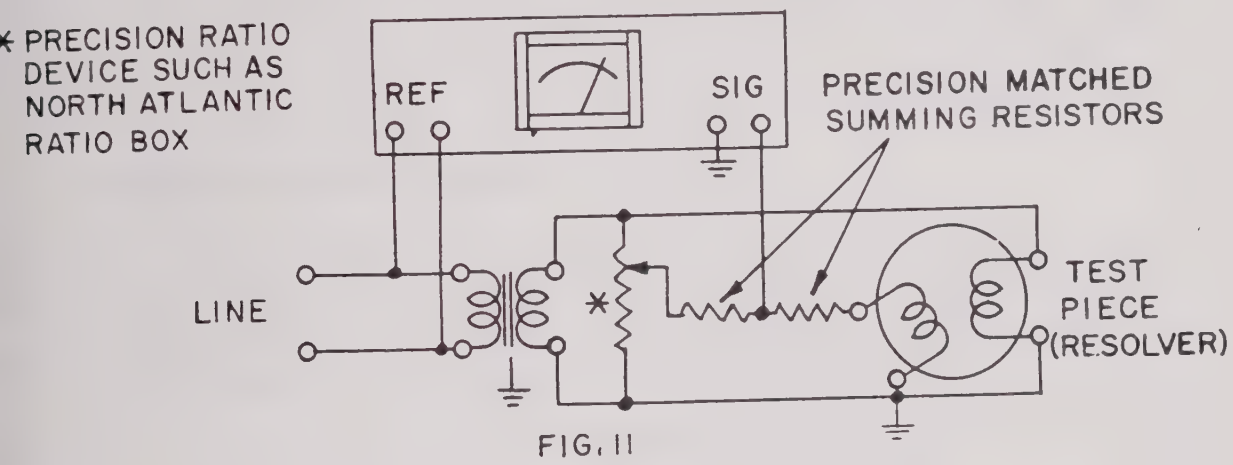

FIG. 11

Transducer Nulling

Applications involving transducers, such as differential transformers or E-Coil pickoffs, are extremely difficult to zero due to the large residual null voltage composed of signal and harmonics from the source as well as harmonics generated in the transducer. Figure (12) shows a system in which a precise in-phase balance can be achieved in the presence of quadrature and harmonics equal to 10 times the full scale sensitivity used. An order greater accuracy in nulling is easily achieved over conventional nulling circuits.

In addition, phase compensation for servo systems or for purposes of linearity compensation are easily accomplished using variations of this same test set-up.

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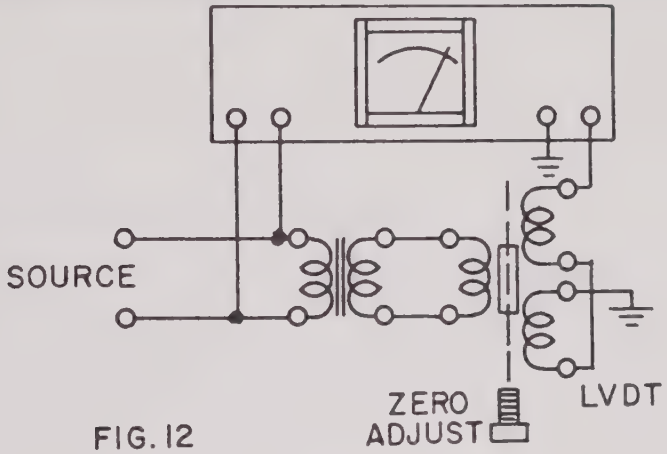

FIG. 12

Synchro Bridge Null Detector

When measuring the electrical errors of synchros, a circuit such as that shown in Figure (13) is used. The phase sensitive characteristics of the Phase Angle Voltmeter as well as the harmonic rejection of the filters and detector makes possible nulls obtainable by conventional instrumentation.

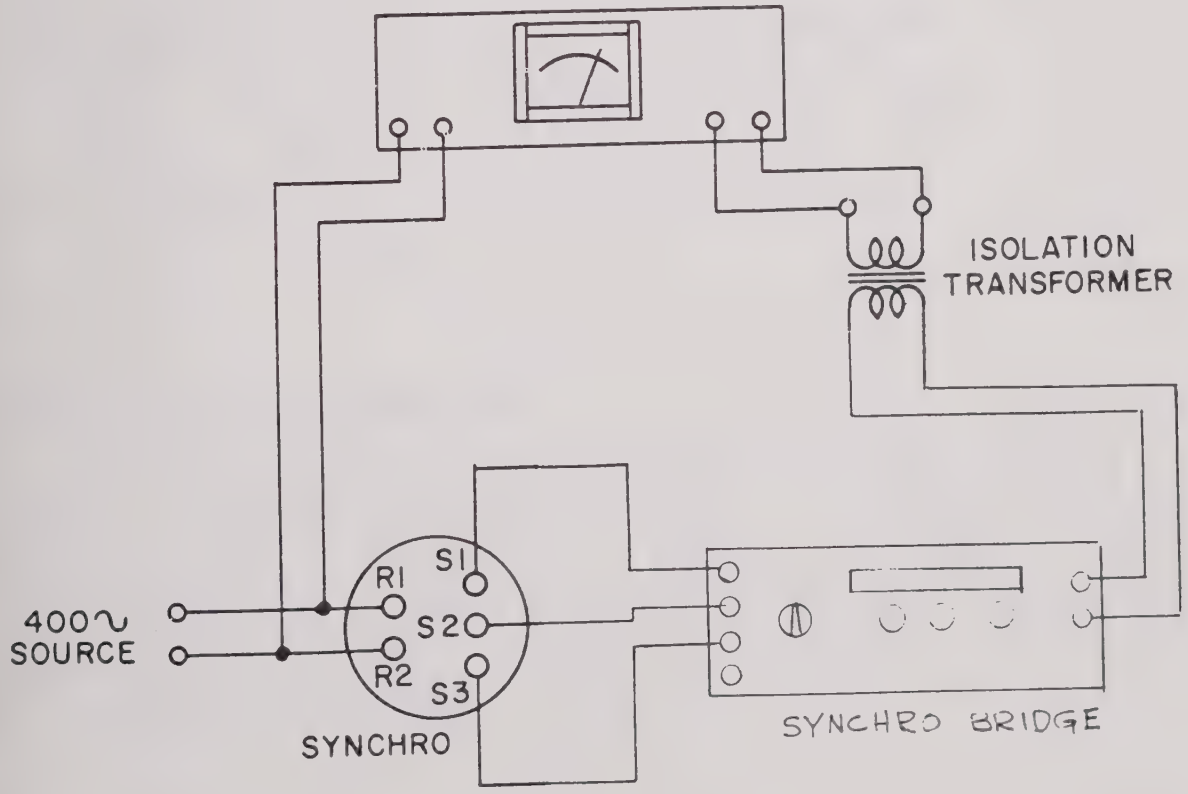

FIG. 13

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Magnetic Amplifier and Thyratron Circuit Alignment

Circuits using thyratron power stages or magnetic amplifier stages cannot be monitored using conventional instruments because measurement errors can be prohibitively large due to the chopped waveforms. If the Phase Angle Voltmeter is used to monitor the output of such devices as shown in Figure (14) the task of alignment for maximum torque or output is straightforward since the meter reading is equivalent to motor output.

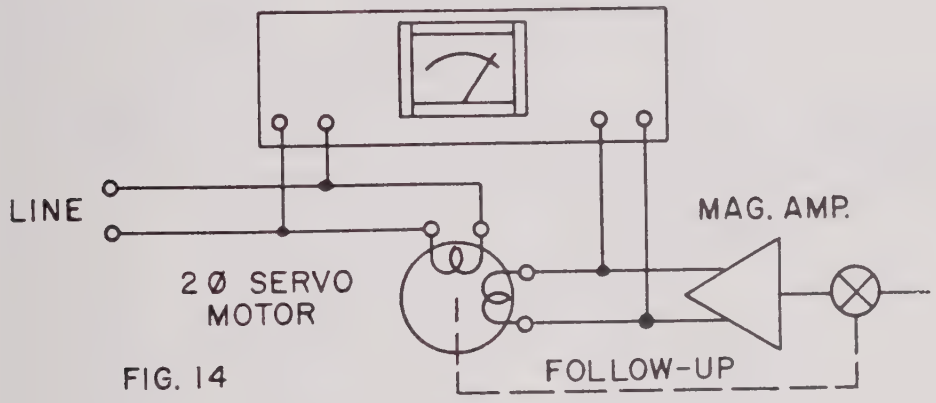

FIG. 14

Carrier Circuits and Amplifiers

Circuits such as those used for phase compensation, summing circuits, amplifiers, etc., must frequently be aligned to reduce quadrature effect to an acceptable minimum and to establish transfer functions at precise values of Phase Angles. Figure (15) is a test setup used to check the phase angle transfer characteristic of a 400 cps carrier amplifier. Switch, S1, is used to adjust exactly the 90 degree point. A precision of trim to a fraction of a degree can be obtained.

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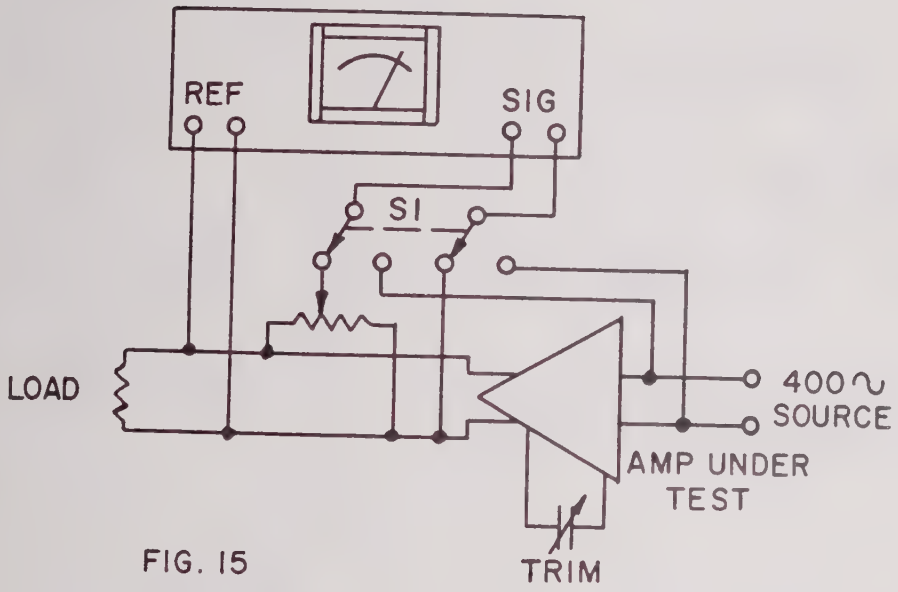

FIG. 15

Transformation Ratio

Numerous circuit arrangements are used in making transformation ratio measurements. Two of the most practical are shown in Figure (16a) and (16b).

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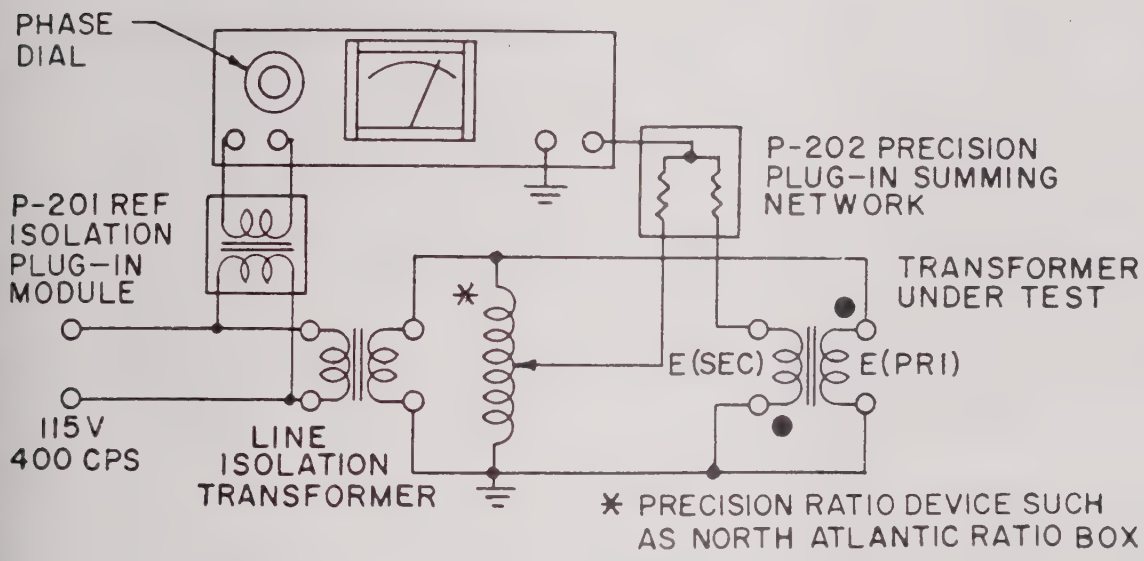

FIGURE 16(a)

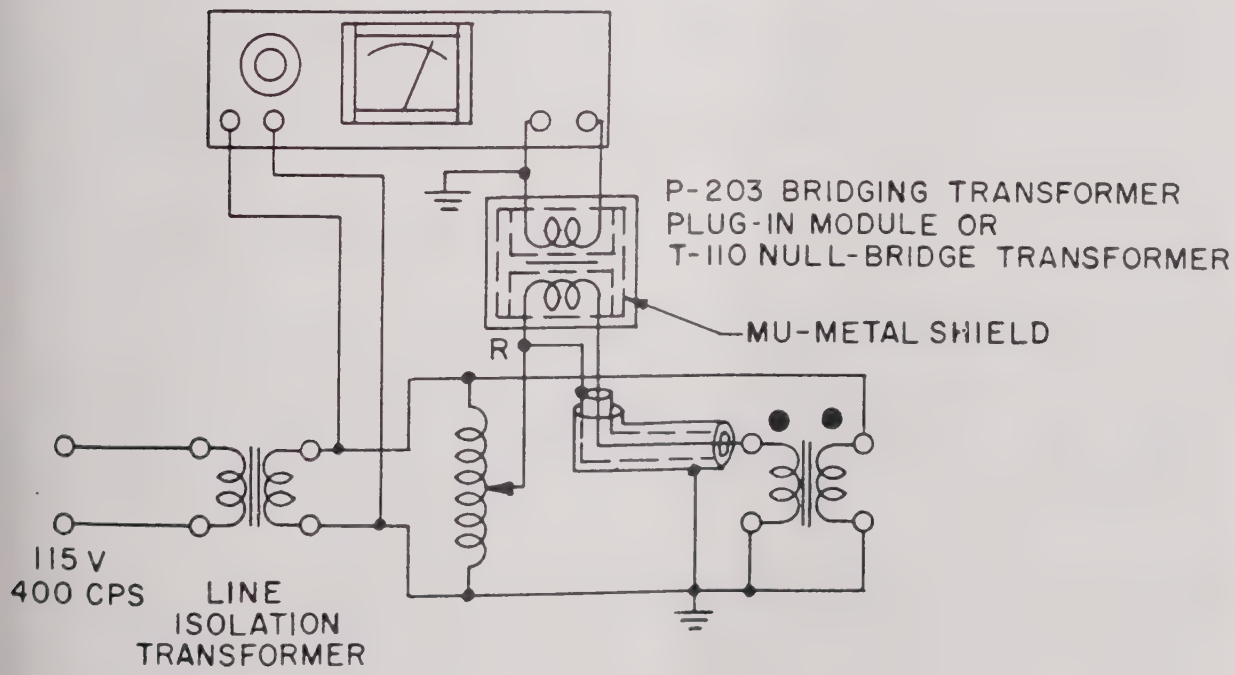

FIGURE 16(b)

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I. SUMMING NETWORK TECHNIQUES

In Figure (16a) the output of the test piece is arranged to have a polarity opposite to that of the ratio device. By means of precision summing resistors - available from NORTH ATLANTIC as the P202 PLUG-IN SUMMARY MODULES, the outputs are added. At null the ratio device will then read the in-phase ratio of the item under test. In this particular test setup a line isolation transformer is utilized so as to avoid grounding one side of theline. For illustrative purposes the NORTH ATLANTIC P-201 PLUG-IN REFERENCE ISOLATION MODULE is also shown as providing circuit isolation on the reference input. This feature can also be built into the voltmeter.

In using the circuit of Figure (16a) care should be exercised in evaluating the errors which can arise due to loading of the test piece by the summing resistors and inaccurate summing due to test piece source impedance.

Phase angle is easily measured using the technique shown in the following section for small angle measurement. Allowance must be made in this case for the 2:1 change in voltmeter sensitivity resulting from the summing network.

II. BRIDGING TRANSFORMER TECHNIQUE

For greater accuracy, the circuit of Figure (16b) has found wide acceptance where the requisite polarity arrangement is feasible. In this case, matching of the test piece output to the ratio device is achieved by using a bridging transformer. A NORTH ATLANTIC P203 BRIDGING TRANSFORMER MODULE is shown, although any good double-shielded isolation transformer with suitable common-mode rejection and low input capacitance would suffice.

Measurement errors in Figure (16b) can occur due to capacitive loading of the test piece or capacitive coupling of the common mode signal into the secondary. The former can be minimized where shielded cables are used by using the so called "driven shield" technique shown in the Figure.

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Common-mode rejection is a function of the transformer shielding, the impedance level of each input to the transformer and the relative values of these impedances. Each setup must be judged by itself as to its suitability for a particular measurement.

Phase angle again is easily measured using the small angle measuring technique shown in the following section. Here allowance must be made for the bridging transformer transformation ratio (1:1 for the NORTH ATLANTIC P203 MODULE).

Both of the above measuring systems are used to provide a direct reading of in-phase ratio. Transformation ratio is by definition the ratio of the absolute magnitude of the secondary to primary voltage. To obtain "transformation ratio" the "in-phase" ratio must be divided by the cosine of the phase shift angle.

Maximum accuracies for both setups require that the Phase Dial be adjusted to compensate for residual phase shifts arising from the various transformers in the system, etc., This is conveniently done by stepping the ratio device and adjusting the Phase Dial to produce zero output when the Function Selector is in the 90° position. Operation will then be correct when the Function Selector is returned to the 0° position.

Small Angle Measurements

Small angle measurements to better than $.01^{\circ}$ can also be made using the setups of Figure (16). The process consists of making the in-phase null, described in the foreoing, using the precision ratio device. Then, by definition the phase shift angle α is:

$$\alpha = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E sec}|} = \text{Tan}^{-1} \frac{\text{E Input (quadrature)}}{|\text{E pri}| \times \text{Ratio}}$$

By measuring the magnitude of the secondary voltage and the quadrature component of the input signal, the angle α can be determined.

For Example:

$$\text{Measured quadrature} = 30.0 \text{ millivolts}$$

$$\text{Secondary voltage} = 30 \text{ volts}$$

$$\alpha = \text{Tan}^{-1} \frac{0.03}{30}$$

$$\cong \frac{0.03}{30} = 0.001 \text{ Rad}$$

$$\equiv 0.001 \times 57.3 = .057 \text{ degrees}$$

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